Genetically modified grains

Market implications for Australian grain growers

Max Foster

Grains Research & Development Corporation

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Australian Bureau of Agricultural and Resource Economics
GPO Box 1563 Canberra 2601

Telephone +61 2 6272 2000   Facsimile +61 2 6272 2001
Internet www.abareconomics.com

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Foreword

Innovation is crucial to enhancing the productivity and, thus, competitiveness of Australian agriculture. The Australian broadacre cropping industry has been particularly successful in this regard, achieving an estimated rate of productivity improvement of 3.2 per cent a year over the past two decades. The use of gene technology to produce genetically modified crops has the potential to further improve the productivity and sustainability of this industry.

The adoption of genetically modified crops in Australia is not a straightforward issue. Various concerns about these crops, even after they have been judged by responsible authorities to be safe for humans and the environment, have manifested themselves in some countries as consumer aversion to genetically modified products. This means that any decision to commercially release genetically modified crops in Australia needs to take into account not only agronomic and environmental factors but also marketing factors.

The purpose in this report is to provide a balanced assessment of the market implications of genetically modified crops for Australian grain growers. The pros and cons of adopting genetically modified crops are explored, with a number of case studies relevant to the Australian grain industry provided. The report is aimed at assisting producers and policy makers in agricultural industries in making decisions about whether to adopt genetically modified crops and in understanding the new policy dynamics arising from the emergence of crop gene technologies.

BRIAN S. FISHER
Executive Director

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The quantitative analysis in this report revolves around the use of a baseline of AGLINK modeling results to 2010. The AGLINK model was developed by the Organisation for Economic Cooperation and Development (OECD). The baseline is the work of officers of ABARE's Agricultural Economics Section. These important foundations to the analysis in this report are acknowledged.

Contents

Tables

Glossary

bioremediation	The use of organisms, particularly micro-organisms, to clean up the environment.
biotechnology	Use of technology, based on living systems, to develop processes and products for commercial, scientific or other purposes. These include specific techniques of plant regeneration and gene manipulation and transfer.
***Bt crop*s**	Crops genetically modified to carry the gene from the soil bacterium *Bacillus thuringiensis*, causing the plant to produce a protein toxic when ingested by certain insects.
clone	A group of genes, cells or organisms derived from a common ancestor. Genetic material is not combined (as in sexual reproduction), so the members of the clone are genetically identical or nearly identical to the parent.
DNA	Deoxyribonucleic acid. This molecule carries the genetic information for most living systems.
gene	A segment of a chromosome. Some genes direct the synthesis of proteins, while others have regulatory functions.
genetic engineering (*also *genetic modification)	The selective, deliberate altering of the genetic material of organisms through the adding or removal of genes
gene technology	Technical and/or scientific methodology involved in the artificial manipulation of an animal or plant genome and operating at either the single or multiple gene level.
genetic transformation	A change in the genetic structure of an organism following the incorporation of foreign DNA.

genome	The total hereditary material of a cell, comprising the entire chromosomal set of a given species.
herbicide tolerant crops	Crops genetically modified to contain a gene that enables them to survive the application of certain herbicides, thus enabling more effective weed control.
identity preservation	Crop or raw material management arrangements that preserve the identity of the source or nature of the materials. The arrangements ensure that a particular crop or raw material is monitored throughout its production and processing chain to ensure its quality integrity.
marker gene	A gene deliberately inserted into a plant to enable plant breeders to select plants that have been successfully genetically modified.
molecular genetics	The study of how genes function to control cellular activities.
pathogen	A disease-causing organism.
promoter	A DNA sequence that is located in front of a gene and controls gene expression. Promoters cause genes to be expressed.
recombinant DNA	The DNA formed by combining segments of DNA from two or more different sources or different regions of a genome.
RNA	Ribonucleic acid. This molecule is similar to DNA and primarily functions to decode the gene instructions for protein synthesis.
traceability	The ability to trace the history, application or location of an entity (in this case, grain) by means of recorded identifications.
transgenic organism	An organism whose genetic structure has been augmented by genetic material from another species, using genetic engineering techniques

Summary

Gene technology — the ability to manipulate the genetic structures of living organisms more directly than through conventional plant and animal breeding — has the potential to markedly increase the rate of productivity improvement in agriculture. The benefits of gene technology should flow through to consumers of agricultural products in the form of lower prices and improved quality.

While Australia has a significant capability in the area of gene technology with grain crops, it has tended to lag in development in the area behind three of its main competitors in world agricultural markets — the United States, Argentina and Canada.

This report is an economic assessment of recent developments with genetically modified grain (GM) crops, with a particular emphasis on the implications for Australian grain growers.

Gene technology developments with broadacre crops

The first GM crop was commercialised in the United States in 1995 and since then the rate of adoption has been remarkable. In 2000 around 40 million hectares of GM crops were harvested throughout the world, mainly soybeans, maize, canola and cotton. This represents around 15 per cent of the total area planted to these crops in 2000. The main producing countries are the United States (67 per cent of the total GM area in 2000) and, to a lesser extent, Argentina (24 per cent) and Canada (8 per cent).

In Australia, no GM grain crops have yet been commercialised, but canola, lupins and field peas are at advanced stages of development. The only GM broadacre crops that have reached commercialisation are an insect resistant cotton that accounted for around 34 per cent of total Australian cotton plantings in 2000 and a herbicide tolerant cotton that accounted for a further 3 per cent.

The rate of development and diffusion of gene technologies in the cropping industry depend on a range of factors. Technical constraints make some

organisms easier to manipulate than others, while the economic benefits from savings in production costs or improved value of quality characteristics vary between species. The size of the potential market, market power, government regulatory arrangements, and arrangements governing international trade will all have an impact on the viability of GM crops.

Consumer acceptance is a key driver. GM crops seem to have been widely accepted in the United States and Canada but are meeting strong consumer resistance in other countries, particularly in Europe. This concern has progressed to the point where a few governments (notably in the European Union) are refusing to accept some GM products and an increasing number of governments are requiring strict labeling of products containing GM material.

Another key driver of the spread of GM crops is the market power generated through the comparatively recent (1980) ability to patent gene sequences and whole species of GM plants, as well as key enabling gene technologies. This represents a marked strengthening of the intellectual property protection regime compared with the more traditional form of plant variety rights.

Consumer acceptance and the market for non-GM grain

The problems of consumer acceptance of GM products arise from perceptions of their safety as food, the risks that they could pose to the environment, ethical concerns and the potential for a limited number of companies to exert control over the food supply chain. These concerns have led to demand from some consumers for grain that is certified to not contain GM material. This requires strict separation of GM grain throughout the production and processing chain, a process that has been termed ‘identity preservation’. Identity preservation adds to the cost of marketing both GM and non-GM grain. It is generally agreed that in a mixed production system of GM and conventional grain, identity preservation requirements add 5–15 per cent to the offer price of certified non-GM grain. Because some adventitious mixing of grain is always possible in mixed production systems, a pragmatic solution has been to allow maximum tolerance levels for GM content in GM-free grain. As a general rule, the lower the tolerance level, the higher the identity preservation costs are likely to be.

Many surveys have been carried out to gauge consumer attitudes to GM products. Generally, the key conclusions of these surveys are that there are widespread concerns about these products in most countries and, initially at least, the concerns have tended to grow as consumers become more aware of just how prevalent GM products are in the food chain. However, there are some indications that these concerns could diminish in the longer term as consumers gain further information about issues with GM foods that concern them.

Market evidence casts some doubt on the extent of consumer concerns. One indication is that GM products have made very substantial inroads into world food markets; for example, soybeans and corn products are being consumed in undiminished quantities, despite the GM status of a large part of the world's supplies, even in Europe where the consumer concerns are the greatest.

A second indication is that there is only patchy evidence of premiums for non-GM grain and oilseeds in world markets. These premiums have not been sufficiently large to offset the agronomic benefits of GM crops. At this stage, the worldwide market for certified non-GM products is only a niche one.

Market implications of the current GM crops

The impact of GM crops on world grain markets can be disentangled from other influences through the use of an econometric model of world agricultural supply and demand. Using an enhanced version of the OECD's AGLINK model, it is estimated that the agronomic benefits (higher yields and lower production costs) of the current generation of GM would lead to a 2 per cent reduction in world prices for oilseeds and coarse grains. There has also been a spillover effect of a 1 per cent reduction in wheat prices. World consumers of grain and grain products are estimated to be better off by around US$5 billion a year. This is because the competitive nature of world agricultural market means that a substantial part of the agronomic benefits are passed on to consumers in the form of lower prices.

However, the imposition of identity preservation requirements on world grain trade would substantially offset these agronomic benefits of GM crops by adding costs. Taking the extreme position that all supplies of GM and non-GM grain need to be identity preserved, and assuming this adds 10 per cent to offer prices of all export grain from GM-producing countries, it is estimated that this would more than offset the agronomic benefits offered by GM crops. That is, world prices would now increase by over 2–3 per cent, compared with the 2–2.5 per cent decline if segregation were not required.

What if Australia adopts GM canola?

Commercial release of canola varieties that are genetically modified to be tolerant of particular herbicides in Australia is possible in the next few seasons. ABARE's assumption about the agronomic benefits of these crops is that they will offer a yield advantage of around 7 per cent, compared with conventional varieties, and a decrease in weed control costs (including seed costs) equivalent to a 3 per cent reduction in total production costs.

Assuming only agronomic benefits (yield improvements and reductions in the cost of production), it is estimated that the adoption of the GM variety would result in Australian canola production increasing by nearly 9 per cent by 2010 and Australian oilseeds exports increasing by around 12 per cent. For Australia to produce the same quantity of canola if it remained GM free, the premium for non-GM canola would have to be around an estimated 10.4 per cent — a level that does not seem to be available on a wide scale in world markets.

If identity preservation were required, then the impact would be quite different. Under the assumption of identity preservation costs adding 10 per cent to overall costs, it is estimated that these Australian gains in the world oilseeds market would be reversed. Australian canola production is estimated to fall by around 1 per cent and Australian oilseeds exports by 2 per cent.

The overall conclusion is that widespread commercial release in Australia may not be justified if elaborate identity preservation arrangements are required. However, production of GM canola may still be profitable in some regions — for example, where weed problems are particularly severe. This is provided that there are no significant spillovers in costs to producers of non-GM grains in those regions.

Market implications of GM wheat

One GM plant developer has flagged that it would like to release GM wheat commercially as early as 2003 in the United States. Wheat grower organisations and wheat marketers in both the United States and Canada have stressed that appropriate identity preservation arrangements need to be in place before wheat varieties of this type are released.

To assess the impact on world markets for agricultural commodities if half of US wheat growers adopted GM wheat, it was assumed that wheat yields rise by 10 per cent compared with existing wheat varieties but at the expense of a 1 per cent increase in total production costs.

On the basis of agronomic benefits alone of these crops, world wheat prices are estimated to decline by 2.6 per cent and the United States is estimated to increase its exports by over 11 per cent, largely at the expense of its competitors in the world wheat market. The loss in comparative advantage in wheat production in Australia would flow through to an estimated 2.6 per cent reduction in wheat exports. (Note that no Australian adoption of GM grains is assumed.)

However, the agronomic benefits are largely negated if identity preservation requirements (adding 10 per cent to the offer prices of all US wheat) are included in the assessment. The world wheat indicator price would decline by only 0.4 per cent, while US wheat exports would increase by only about 1 per cent. The impact on Australia's comparative advantage in wheat production would then be only negligible, with exports declining by 0.4 per cent.

On the basis of agronomic benefits alone, world consumers of wheat products would be better off by US$5.7 billion in constant (2001) dollars through lower prices. The introduction of identity preservation requirements is estimated to reduce these benefits to US$2.1 billion.

Implications of the Biosafety Protocol for world grain markets

The Biosafety Protocol will be an important determinant of market access for GM products. When finalised, the Biosafety Protocol will be an international agreement between the member countries of the United Nations Convention on Biodiversity that sets the rules for movements across national borders of living modified organisms that may affect the conservation and sustainable use of biodiversity.

The main economic implications of the protocol arise from any potential increase in costs of trading products affected by the documentation regime, and from its potential effect on the adoption of GM organisms. Commercial disciplines in the market place are largely leading to the same sort of documentation requirements as would be needed under the protocol. Moreover, the protocol is helping to build the capacity in poorer countries to deal with the biosafety issues with imports of living modified organisms, and it may facilitate trade, rather than impose an extra burden on trade.

The modeling results using AGLINK show that for every 1 per cent that the operation of the Biosafety Protocol raises grain export transaction costs above that required under normal commercial disciplines, the welfare of the world's consumers of grain products would be lowered by an estimated US$330 million a year. There is a significant tendency for GM producing countries to export more of their GM crops in processed form rather than in unprocessed form.

The protocol holds that scientific uncertainty brought about by insufficient scientific information and knowledge of the impact of the organism shall not prevent a decision on the import of that organism. Scientific uncertainty could potentially be used to impose unjustifiable restrictions on trade and could weaken the current scientific basis of risk assessment.

Conclusions

In the main, the current generation of GM grain crops apparently offers significant agronomic benefits and, thus, the promise of lower prices to consumers. The next generation of GM crops is likely to offer significant benefits in terms of quality. However, if the problems of consumer acceptance of GM foods require elaborate identity preservation arrangements, then these benefits could be largely negated.

In the short run, at least, Australian grain growers are unlikely to be greatly disadvantaged by not having access to GM grain crops. And they may even profit if premiums for non-GM grain evolve in the market place. The threat to the long run competitiveness of the Australian grain industry is that preferences for non-GM products may erode as the novelty of gene technology diminishes and the industry faces having lagged behind in its development in this area.

Price premiums for non-GM grain will reflect the strength of consumer aversion to GM crops. If these premiums are not large enough to offset the agronomic advantages that GM crops may have over conventional ones, then GM crops may eventually dominate the world grain markets.

1

Introduction

Gene technology is providing plant breeders with the ability to manipulate the building blocks of life in ways not previously possible, or more difficult, through traditional breeding methods. These techniques, combined with rapid advances in genomics — the mapping of genes and their function in living organisms — are enhancing this ability to modify the characteristics of living organisms.

The developments have the potential to increase markedly the rate of productivity improvement in agriculture. Major agricultural innovations from genetic manipulation are expected to include crops and livestock that are more resistant to disease-causing organisms, are more able to make efficient use of nutrients, have improved product quality, and are better adapted to environmental stress. The benefits of gene technology are likely to flow through to consumers in the form of a more diverse range of products that are cheaper and improved in quality.

Some of Australia's key competitors in world markets for agricultural commodities — most notably, the United States, Argentina and Canada — lead the world by a large margin in the development and use of gene technology in agriculture. There is concern that Australia's agricultural industries, if they do not match the pace of international developments in this area, could face a marked deterioration in their international competitiveness.

The initial forms of GM grains and oilseed emerged as a commercial proposition in the mid-1990s and have been rapidly adopted by growers in the United States, Argentina and Canada. However, while the development of GM grains appears to have led to some significant cost savings in production and perhaps some quality improvements, there have been growing concerns in recent years about consumer acceptance of products of these crops, particularly in Europe.

In response to these alleged consumer concerns, policymakers in some countries, most notably the European Union, are imposing market access restrictions and conditions, such as bans on GM grain imports and mandatory labeling to inform consumers where products contain GM inputs.

The aim in this report is to explore the potential market implications of current and future developments in gene technology with broadacre crops. The approach adopted was to assemble and review available information on agronomic factors, consumer preferences and market access issues associated with these crops. This information was then used in conjunction with an econometric model of world agriculture (AGLINK) to assess potential market implications.

The GM crops of most interest to the Australian broadacre cropping industry are wheat, canola, rice, pulses and coarse grains, but it is important to also consider gene technology developments with the other closely competing crops, soybeans and cotton. Background information on the nature of world markets for these crops is provided in appendixes A and B.

2

Progress of plant gene technology

This chapter is an overview of plant gene technology developments, with a particular focus on grains. The OECD Biotrack database contains details of over 9600 field trials of GM organisms that have been undertaken (see OECD 2001). Of the total number of field trials in this database, 98 per cent were with plants, 1 per cent with bacteria, 0.2 per cent with viruses, 0.13 per cent with fungi and 0.16 per cent with animals.

The figures for field trials probably substantially understate the effort being put into genetic modification with micro-organisms in particular, because these experiments are usually conducted in laboratories. Genetic modification with animals is less advanced than with plants. However, recent developments in cloning techniques have the potential to increase genetic engineering with animals (Ayares 1999).

Progress of developments

Brenner (1998) explains that developments in gene technology with plants can be divided into three broad categories — improving production traits, changing output characteristics or replacing other production systems (table 1). Around about three-quarters of the field trails have been in the first category — improved production traits (figure A). Work on improving output traits is reasonably advanced, while replacement of other production systems is still some years away.

There is increased 'multiple stacking' of traits whereby more than one trait is incorporated into the organism. Cotton plants with both insect resistance and herbicide tolerance, for example, have already been commercialised.

Some concerns have been raised about the environmental safety of some GM plants. The main concerns are outlined in box 1. To safeguard against adverse environmental impacts, most countries have regulations aimed at ensuring the environmental safety of GM organisms before they are generally released. An important aspect of assessing risks of GM plants before allowing commercial release are field trials conducted under strict rules aimed at not allowing the escape of the GM organisms.

1 Categories of developments in genetic engineering of plants

Category 1: improved traits	Category 2: improved output traits	Category 3: replacement of other production systems
• Insect resistance • Herbicide tolerance • Viral resistance • Fungal resistance • Nematodal resistance • Bacterial resistance • Seed or plant sterility • Tolerance of environmental stress — for example, frost, drought, saline soils • Yield — for example, improved nitrogen fixation process	• Nutrient characteristics – increased macro-nutrients such as protein, starch, oil, sucrose or gluten – increased micro-nutrients such as vitamins – altered product quality such as high oleic acid soybeans or high laurate canola • Flavor • Processing characteristics — for example, high solids tomatoes • Storage characteristics — for example altered ripening tomatoes or resistance to browning in potatoes	• Biologically based polymers, plasticisers and lubricants (replaces petrochemical oil) • Nutraceuticals — that is, crop products that provide a vehicle for boosting intake of disease-preventing micronutrients (replaces traditional food fortification methods) • Pharmaceuticals and antibiotics (replacing traditional fermentation processes)

1 Possible environmental concerns associated with genetically modified plants

The key scientific considerations with environmental release of GM crops are detailed in McLean, Waterhouse, Evans and Gibbs (1997). A general concern is that insufficient is known about the long term effects of any GM organism on the environment and thus on the sustainability of agricultural systems based on its use.

Some examples of specific concerns about GM plants are:

- that herbicide resistant plants will pass their resistance on to their wild weedy relatives, leading to an increased weed problem or even becoming a weed problem themselves;
- that virus resistant plants will result in the evolution of more virulent viruses through a naturally occurring process known as RNA recombination;

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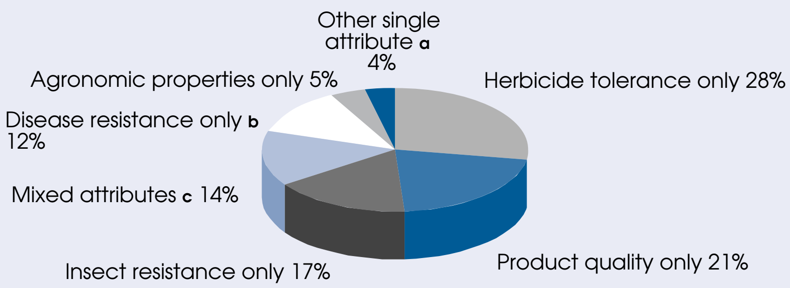
- that plants engineered to contain insecticides will accelerate the process of insects developing resistance to externally applied insecticides with similar chemical structures; and
- that Bt corn plants may represent a risk to nontarget insects, such as the larvae of the monarch butterfly, because the Bt toxin is expressed in their pollen, which dispersed over at least 60 metres by the wind (Losey, Raynor and Carter 1999).

Genetic engineering can also lead to organisms that have beneficial effects on the environment. Examples include plants with inbuilt pesticides (which therefore require less externally applied chemical pesticides that may be harmful to the wider environment) and plants and micro-organisms with heightened tolerance of toxic elements in the soil (and therefore enable bioremediation of degraded land).

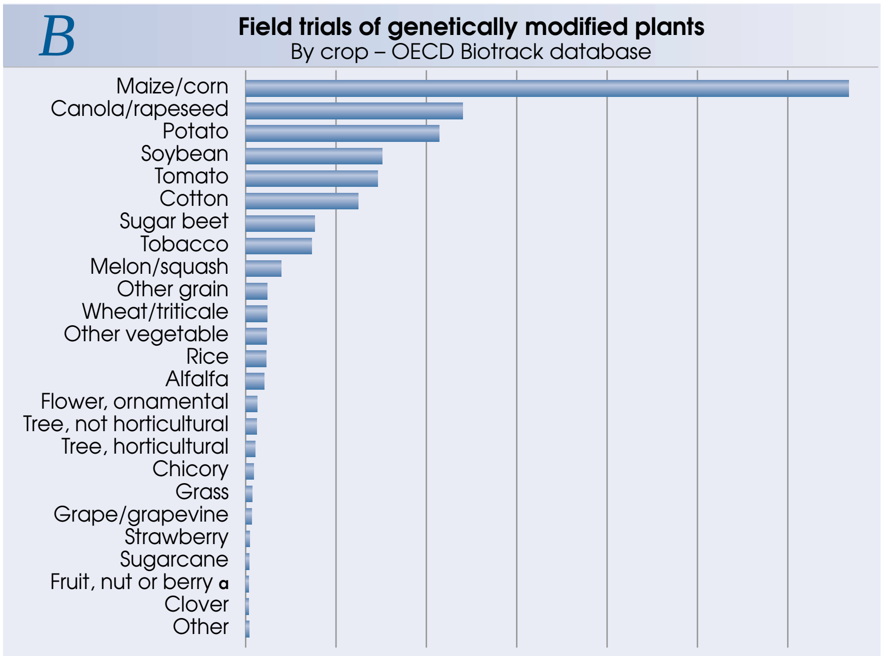
Plants with tolerance to herbicides are the most trialed of GM crops attributes in plant genetic engineering — 27 per cent of all field trials are for plants that are purely herbicide tolerant and a further 15 per cent contain this attribute in combination with other added attributes. Product quality and insect resistance are the other main categories of trials (figure A).

Plants with mixed attributes (mixed stacked genes) make up 14 per cent of all OECD field trials. (Where a gene is inserted for the purposes of a marker, it is not counted as an additional attribute.) Around 40 per cent of these plants have the combination of insect resistance and herbicide tolerance.

A **Field trials of genetically modified plants**
By category – OECD Biotrack database



a Includes characteristics such as confidential, marker genes, male sterility and fertility restorers. **b** Bacterial, fungal, nematodal and viral resistance. **c** Marker gene insertions are not counted as an additional attribute in this category.
Source: OECD (2001).



a Not from tree.
Source: OECD (2001).

Based on data for OECD countries, maize (or corn) is the most actively trialed of the GM plants, accounting for over one-third of total OECD field trials (figure B). Together, the key broadacre summer crops of maize, soybeans and cotton make up nearly a half of the total trials. Of the broadacre winter crops, canola/rapeseed accounts for 12 per cent of total trials and is ranked second overall. However, the other key broadacre winter crops, wheat and barley, make up only 1.4 per cent of the total.

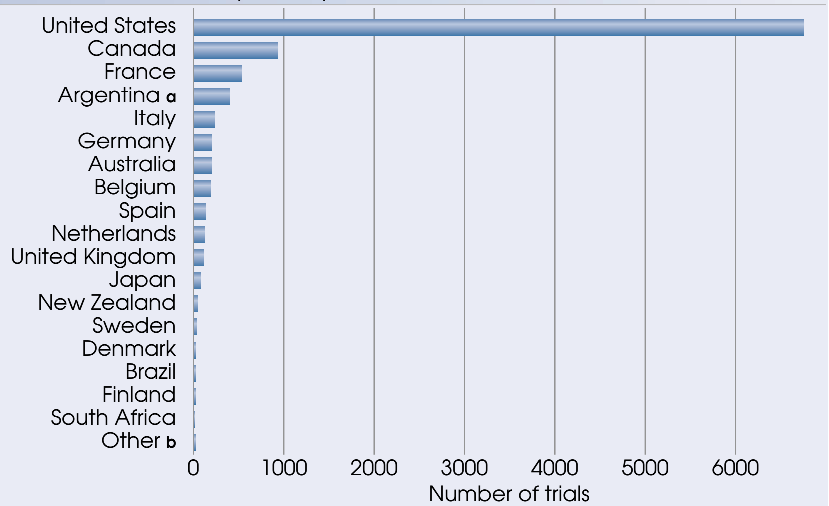
The United States dominates the world in genetic modification of plants, accounting for around 70 per cent of the total field trials in OECD countries (figure C). The United States operates a Coordinated Framework for Regulation of Biotechnology that applies statutes and their regulations and guidelines on the environmental release of products of biotechnology. As well, where the framework is inadequate, regulatory policy is evolving through formal and informal understandings between agencies (Hallerman 2001). Concern about possible adverse reactions to GM products recently caused the United States to revisit its regulatory arrangements regarding agricultural biotechnology; in May 2000 US President Clinton announced a number of initiatives aimed at strengthening regulation of these products and improving consumer access to information about them.

In the European Union, eighteen GM products have been approved for marketing under Directive 90/220 (Agbios 2001) and nearly 1600 field trials of GM plants have occurred. However, no new GM crop varieties have been approved since April 1998 and the Environment Ministers of the European Union agreed in June 1999 to what amounts to a moratorium on further commercial releases of GM organisms until (according to Hughes 1999) at least 2002. The European Union also revoked approvals on transgenic plants containing antibiotic resistant marker genes because these could somehow lead to increased resistance of bacteria to antibiotics.

In February 2001 the European Parliament passed strict new rules for testing and monitoring the safety of GM crops, apparently paving the way for the lifting of the de facto moratorium on the approval of new GM varieties. However, six European Union countries almost immediately imposed conditions on the continued passage of the legislation, requiring that rules be in place to ensure all GM products can be traced back to their source (presumably as a safety check). This requirement is expected to delay the approval process for at least eighteen months.

There are signs that the rates of trialing and commercial release of new genetically organisms are slowing. In the United States, the main proponent of agricultural gene technology, field trials declined from a peak of 1086 in

C **Field trials of genetically modified plants,**
By country – OECD Biotrack database



a From CONABIA (2001). **b** Russian Federation, Portugal, Bulgaria, Austria and Switzerland.
Sources: OECD (2001), ABARE.

1998 to 936 in 2000. Petitions for deregulation (commercial release) declined from a peak of 16 in 1995 to only six in 2000. A key factor in this slowdown has been the consumer reaction to GM products. Related to this consumer reaction is the virtual moratorium in the European Union. This makes it problematic to commercially release new GM varieties in grain exporting countries, even if they are not intended to be exported to the European market, because they could 'contaminate' other grain supplies. For example, Argentina has yet to approve varieties of herbicide tolerant corn because there are concerns that this would damage its export markets in Europe, particularly in Spain and Portugal. Consumer acceptance is discussed in chapter 3.

China has moved cautiously in approving GM crops, approving only insect resistant cotton for commercial release. New rules from June 2001 require more extensive controls on, and testing of, GM crops before commercial release. The view has been expressed that these new rules could add as much as two years to the approval process for GM crops such as corn that have already been commercially released in the United States (Lococo 2001).

Intellectual property rights are an important influence on the rate of development of gene technologies and the rate at which these technologies diffuse through industry. Forms of intellectual property include utility patents, plant variety rights, trademarks and trade secrets. Utility patents — the devices that have traditionally applied to industrial innovations — have assumed heightened importance as drivers of technological progress in gene technology. With plants, they represent stronger property protection than the more traditional form of protection of plant variety rights.

Important accumulations in knowledge are occurring through 'advanced genomics' (which involves mapping and sequencing of the genetic structure of organisms at the molecular level). This process provides the means of identifying and controlling the genes that are linked to agronomically important traits. Genome databases for a number of different organisms exist at various states of completion throughout the world (including one for the human genome).

In early 2001 Syngenta (the world's largest agribusiness corporation) and Myriad Genetics announced that they had sequenced the complete rice genome. This was the first time for a crop plant and involved sequencing 430 million DNA bases. Only commercial access to the sequence will be allowed. A publicly funded project for the sequencing of the rice genome is still three years from completion (Dickson and Cyranoski 2001).

2 Patents and gene technology

A property right gives the inventor control over who uses their innovation and thus the ability to appropriate at least part of the resulting benefits. Patents have the added social benefit of making that knowledge part of the public domain so there is less effort in researching what has already been discovered.

It is recognised that there is a fundamental policy tension with patents: they provide incentives to create worthwhile knowledge but, once created, they hinder its spread. Setting the length of time over which the patent applies and the breadth of exclusion (scope) is an attempt to balance the conflicting effects of encouragement and market power.

All major industrialised countries now routinely grant patents for living organisms (including yeasts, bacteria, viruses, mammalian cell lines and plants) as well as for the technologies that enable transformation. Claims to human beings, including embryos, are either explicitly excluded by clauses in legislation or regarded as contrary to other laws and therefore not allowable. Australia explicitly excludes claims to ‘human beings and biological processes for their generation’ under the Patents Act 1990. A patent to recombinant DNA technology (now expired) was granted in 1980 but the overseer of the patent, Stanford University, provided inexpensive licences to nearly all researchers and companies involved in biotechnology.

The first US patent approved for a transgenic plant was granted in 1992 to the company Agracetus for transgenic cotton. It confers rights to all transgenic cotton, irrespective of the nature of transformation. Agracetus was granted both US and European patents on all transgenic soybean varieties in 1994. In January 1995, Novartis Corporation received a US patent for genetically engineered wheat.

However, there is vigorous debate about applying current patent laws to innovations in biotechnology, with legal challenges to all the above patents (Blakeney 1999). The US Department of Agriculture in 1998 successfully challenged the breadth of the Agracetus patent for transgenic cotton and its application to plants other than cotton.

A wide range of enabling technologies have also been patented, including the transformation technologies by which genes are inserted, the promoters that control gene expression (a type of on–off switch), selectable markers that are used to select organisms that have been successfully transformed, and gene silencing technology (which can be used to suppress gene expression).

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It is also now possible to patent gene sequences. The first US patent for expressed sequence tags — short sequences of DNA commonly used to decode longer sequences — was granted to Incite Pharmaceuticals in 1998.

Combined with the massive expansion in intellectual property generated by biotechnology in recent years, there has also been a tendency for ownership of key areas of this property to become concentrated. There has been a flurry of merger and acquisition activity among biotechnology companies, seed companies and companies that specialise in information on the structure of plant genomes.

The ability to engineer plants that produce sterile seeds is also useful in protecting intellectual property. Farmers must return to the seed companies each year to purchase their seed for planting, rather than retaining seed from their own harvest. (Crops that are typically hybridised, such as corn, already have some protection in this form because yields decline with subsequent generations.)

The patent system as applied to plant innovations has raised a number of concerns. First, some of the patents being granted are very broad; for example, US and European patents for cotton and soybeans confer rights to all GM crops of these types, irrespective of the nature of the transformation. Second, unlike plant variety rights arrangements, patents do not exempt breeders from breeding new varieties from protected ones. Further, they do not allow farmers the right to reproduce varieties for their own use or to retain GM seed from the previous harvest. Third, licensing fees are very high and, according to Peacock (1998), some holders of plant patents are unwilling to grant licences to their technologies.

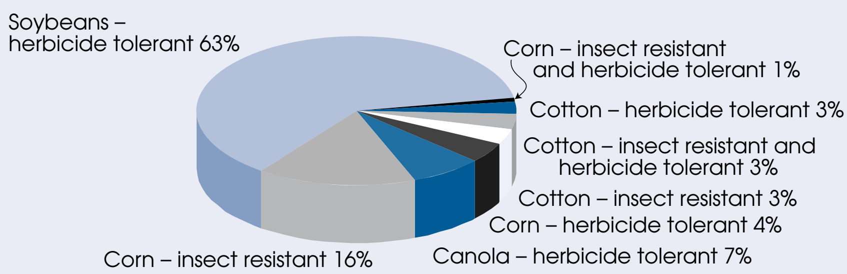
The maze of patents that apply to genetic modification of plants can make it difficult to develop a new plant and perhaps put small firms at a competitive disadvantage. This is illustrated by the case of Golden Rice — a vitamin A enriched rice — whose development has involved the use of 70 patents from 32 companies and universities (Schiermeier 2001).

The World Trade Organisation Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) is an attempt to ensure intellectual property rights are granted on a consistent basis throughout the member countries.

Commercial releases of plants

Approval for commercial planting of a GM plant occurred in 1992 in the United States with a tomato with altered ripening characteristics. Sixty-five different forms of GM plant have since been approved for commercial planting in various countries throughout the world. (For a full listing, by country, see table B1.)

D Genetically modified crop plantings, by trait, 2001



The commercialised GM crops that have been successful in terms of levels of adoption have been herbicide tolerant soybeans and canola, and insect resistant and herbicide tolerant cotton and corn (figure D). GM soybeans (herbicide tolerant) were approved for commercial release in Brazil in 1999. However, a Brazilian court ruling in mid-2000 placed a ban on commercial sale of the soybeans until an environmental impact assessment is conducted. This ruling has been upheld in appeal once, but is facing a second appeal.

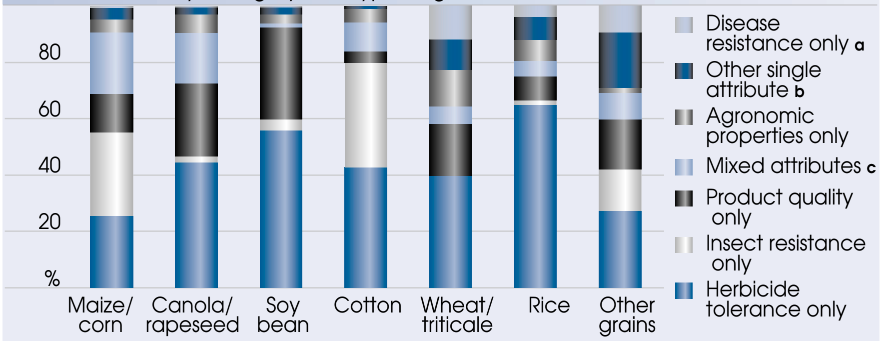
The market impacts of GM horticultural crops have been slight. Insect resistant potatoes peaked at about 3 per cent of US production in 1999. According to Gianessi and Carpenter (1999), cost savings and yield improvements with this variety have been virtually nonexistent, although there may be some improvement in quality in terms of skin smoothness. The developer will stop selling seed for this potato variety to north American farmers in 2001 (Kilman 2001). The Flavr Savr® tomato has not been a commercial success, given relatively poor yields and insufficient disease resistance traits, despite attracting some favorable comment from consumers (Traynor 1996).

Grain developments

Field trials of grains

Compared with nongrain research, the developments in grains have a greater emphasis on herbicide tolerance and insect resistance traits, and less emphasis on disease resistance and product quality traits. The categories of genetic engineering for each of the main grain types are shown in figure E.

E **Field trials of grain**
By category and type of grain – OECD Biotrack database



a Bacterial, fungal, nematodal and viral resistance. **b** Marker genes, confidential, male sterility and fertility restorers. **c** Marker genes are not counted as an additional characteristic in this category.
Source: OECD (2001).

Wheat makes up only 10 per cent of total field trials with grains, reflecting that until recently it has been more difficult than the other grains to modify. Herbicide tolerance is an important trait being sought with wheat, but so is resistance to fungal diseases, reflecting the importance of rust-like diseases to wheat in many countries (figure E). The United States accounts for 68 per cent of total field trials of wheat, with Canada (18 per cent), European Union (11 per cent) and Australia (3 per cent) making up the bulk of the remainder.

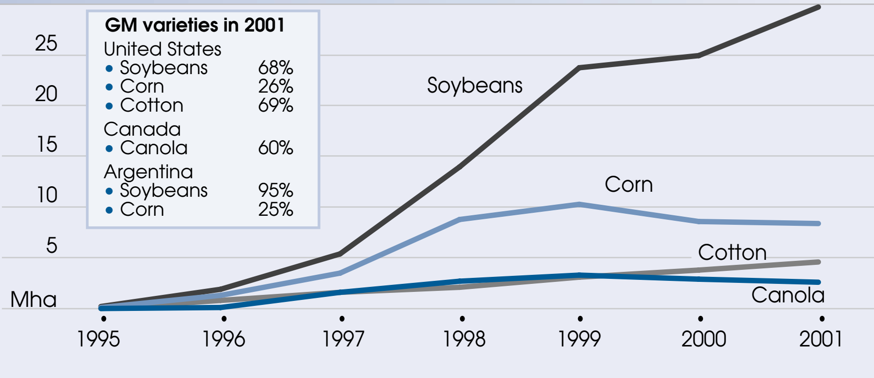
Commercial areas of GM crops

Areas harvested of GM grain crops are shown in table 2 (for selected countries) and illustrated in figure F (for all countries). World areas of GM crops increased rapidly until 1999, but 2000 was a watershed year for these crops. Except for cotton, the rate of growth substantially slowed, even reversing in the cases of corn and canola (figure F). This slowdown largely reflected problems of acceptance with significant consumer blocs and perhaps poorer-than-expected agronomic performances of some crops.

The cooling of enthusiasm was mainly in North America. Argentina increased its area planted to GM crops in 2000 — up by 10 per cent (1.9 million hectares) for soybeans and 14 per cent (0.4 million hectares) for corn. China has also begun to adopt GM crops on a larger scale, with estimated plantings of insect resistant cotton of 300 000 hectares in 2000.

World GM soybean areas are forecast to again grow strongly in 2001, following the downturn in 2000, while the steady growth in cotton plantings is also

F **World harvested area of genetically modified crops**



expected to continue. Many US soybean growers seem to be responding to the signal that premiums for non-GM soybeans have failed to develop to the extent where they outweigh the agronomic benefits of growing GM soybeans. (The issue of premiums for non-GM grain is discussed in more detail later in this report.) GM corn and canola areas are forecast to again decline in 2001.

2 **Estimated area harvested of genetically modified grain and oilseeds crops, selected countries**

	1996 '000 ha	1997 '000 ha	1998 '000 ha	1999 '000 ha	2000 '000 ha	2001 f '000 ha
United States						
Soybeans, herbicide tolerant	1 897	4 755	11 973	16 711	15 891	20 750
Corn						
– insect resistant	412	2 235	6 169	7 131	5 298	5 048
– herbicide tolerant	882	1 265	1 469	1 141	1 766	1 963
– insect resistant and herbicide tolerant	0	0	1 175	1 141	294	280
Total GM corn	1 294	3 500	8 813	9 413	7 359	7 292
Cotton						
– insect resistant	762	977	562	869	795	702
– herbicide tolerant	0	570	995	1 521	1 378	1 728
– insect resistant and herbicide tolerant	0	0	432	598	1 060	1 296
Total GM cotton	762	1 546	1 989	2 988	3 233	3 726
Canola, herbicide tolerant	0	0	0	85	122	120

Continued ➩

2 Estimated area harvested of genetically modified grain and oilseeds crops, selected countries *continued*

	1996 '000 ha	**1997** '000 ha	**1998** '000 ha	**1999** '000 ha	**2000** '000 ha	**2001 f** '000 ha
Argentina						
Soybeans, herbicide tolerant	31	695	2 041	6 856	8 865	8 835
Corn, all GM varieties						
– insect resistant	34	32	26	620	560	700
– herbicide tolerant	0	0	0	0	0	0
– insect resistant and herbicide tolerant	0	0	0	0	0	0
Total GM corn	34	32	26	620	560	700
Cotton, all GM varieties	0	0	0	0	8	22
Canada						
Canola, herbicide tolerant	138	1 610	2 715	3 227	2 793	2 300
Soybeans, herbicide tolerant	0	0	0	200	212	217
Corn, all GM varieties	0	0	0	230	215	238
China						
Cotton, insect resistant	0	0	0	0	300	500
Australia						
Cotton						
– insect resistant	30	60	84	130	165	180
– herbicide tolerant	0	0	0	0	14	77
Total GM cotton	30	60	84	130	179	258
South Africa						
Corn, all GM varieties	0	0	0	0	132	132
Cotton, all GM varieties	0	0	0	0	10	10
World (canola, corn, cotton, soybeans)						
Total harvested area	260 169	262 221	268 682	271 085	271 328	271 805
Total GM area	4 185	12 197	27 641	40 461	39 959	45 367
Proportion genetically modified (%) **a**	*2*	*5*	*10*	*15*	*15*	*17*

a Includes areas and countries not listed above. Other countries that are growing small commercial areas of GM grain crops (less than 10 000 hectares) include Bulgaria, Paraguay and Romania.
f Forecast.
Sources: James (1999, 2000); US Department of Agriculture (2001c); ABARE.

In the pipeline

No GM varieties of wheat, rice or barley have been commercialised. In January 2001 the life sciences company, Monsanto, began the registration process in the United States for wheat that is genetically modified to be tolerant to a herbicide. Monsanto signaled its intention to bring to market this so-called 'Roundup Ready' wheat between 2003 and 2005.

In 1999 a research group reported modified forms of rice that provide significant amounts of beta-carotene (the precursor of vitamin A) and dietary iron. (Conventional rice virtually does not contain either of these.) This rice, popularly termed 'golden rice' contains a gene from the Erwinia bacteria and two genes from the daffodil. It is claimed that around 300 grams of this rice will provide enough beta-carotene to meet an adult's daily vitamin A requirement (Grainger 2000).

According to Prakash (1999), the International Rice Research Institute leads an international effort aimed at transforming rice varieties to be resistant to insects and key diseases such as bacterial blight and fungal sheath blight (to which no existing varieties are resistant). Other institute programs could produce varieties with enhanced tolerance to water submersion or the ability to fix nitrogen from the atmosphere.

By introducing the photosynthesis genes of maize into rice, researchers in Japan claim to have demonstrated rice strains that could boost photosynthesis and grain yields by up to 35 per cent.

A gene technology patented by the Delta and Pine Land Company and the US Department of Agriculture — the Technology Protection System ('Terminator') — has the potential to markedly enhance the market power of developers of GM plants. This technology enables plants that produce seeds that are not capable of germination in the second generation. Thus, farmers are unable to keep seed from their harvest for the next season and they must buy their seed each season from the seed company. Hybrid seeds already offer some protection of this form because the yields of second generation progeny of hybrids usually decline. A number of companies are developing or patenting alternative technologies for ensuring sterile seeds.

Australian developments

As with virtually all other countries in the world, the possible environmental implications of GM plants are evaluated before these plants are allowed to be planted in open field trials in Australia. The assessor has been a nonstatutory organisation called the Genetic Manipulation Advisory Committee (GMAC), a self regulatory body established by the scientific community in Australia. An agency with statutory powers under the *Gene Technology Act 2000* — the Office of the Gene Technology Regulator — will assume this role from mid-2001. Government policy and the legislation provide for full recovery from gene technology researchers of the costs associated with the operation of the new system, after an initial two year period of grace. KPMG (2000) pointed to the possibility of a cost recovery program being a significant deterrent to investment in gene technology research in Australia, especially in the first few years of operation of the office.

The information from field trials provides an important part of the information used to assess the environmental risks of commercial release. There have been around 113 field trials of GM plants in Australia (table B2). (Each of these field trials can involve many different plots in many different locations. With cotton, a number of these fields trials have been for seed increase before commercial release.) A number of field trials of other GM organisms have been related to crop production, including modified rhizobium for improved nitrogen fixing in the soil and genetic marking of bollworms to enable better understanding of how this crop pest multiplies.

Cotton and canola are the most trialed grain crops in Australia. Developments in the area of lupins and field peas are largely unique to Australia, reflecting that these crops are important in Australian crop rotations but not in the rest of the world.

While only a few field trials of GM wheat have been undertaken in Australia, there is a vigorous research program in contained experiments (laboratories and greenhouses). Some of the genetic modifications of wheat that are being researched in Australia involve resistance to barley yellow dwarf virus, improved elastic properties of wheat dough, and increased yields through altered carbohydrate metabolisms.

Current and prospective commercial releases in Australia

There have been four commercial releases of GM crops in Australia: an insect resistant (Bt) cotton (Ingard®) in 1996; a carnation with improved vase life in 1994; a blue carnation in 1996; and an herbicide tolerant cotton in 2000. The insect resistant cotton has been grown on a commercial scale in Australia since 1995-96. Throughout this period, plantings have been limited to levels permitted by regulatory authorities. The main reason for adopting this variety seemed to be improved environmental outcomes and better community relations associated with reduced chemical pesticide use. In the first three seasons of the variety's use, monetary returns were only similar to those from using conventional cotton. A 40–50 per cent saving in pesticide use with the GM variety was offset by a hefty technology fee and a slight yield penalty. The 1999-2000 season was the first time that insect resistant cotton returned a monetary benefit — an average $72 a hectare improvement in returns (CRDC 2000).

A number of commercial releases of grains are possible in the near future, including canola (2003) and lupins and field peas (around 2005). The Centre for Legumes in Mediterranean Agriculture has lodged an application for commercial release of herbicide tolerant lupins. GMAC considered that the release would not raise safety concerns but has asked the centre to provide further details on how the variety will be managed on farm. Canola that has been genetically modified to be herbicide tolerant has been extensively trialed in Australia and two developers — Aventis Crop Science and Monsanto Australia — seem likely to apply to the Office of the Gene Technology Regulator soon for approval for commercial release, potentially in 2003.

Economic benefits of modified crops

Reflecting growers' perception of benefits, the rate of adoption of GM crops in north America, particularly the United States, has been substantial (figure F).

The claimed farm level benefits from using these GM crops in north America, gathered from different sources, are summarised in table 3. (The Carpenter and Gianessi (2001) entries in this table are usually summaries from a range of sources.) Perhaps the most rigorous of these studies — US Department of Agriculture (1999a) — looked at the yield performance of these crops in the three years to 1998. It found that the use of insect resistant maize and cotton was associated with higher yields than those of conventional equivalents in most years for some regions. Herbicide tolerant soybeans were only associated with higher yields in some regions in 1997. The caveat on these results was that crop yield differences between adopters and nonadopters of these crops could also be due to other factors not controlled for in the analyses.

Using data for 1997, the same US Department of Agriculture study found that herbicide tolerant technology significantly reduced herbicide treatments

3 Benefits from selected genetically modified crops in north America

Crop type and study	Benefits and costs compared with conventional crops: Description	Estimated gain (loss) US$/ha
Canola, herbicide tolerant		
Fulton and Keyowski (1999), for Canada in 1999	• Yield — average 7.5 per cent lower • Weed control system cost (technology fee plus herbicide costs) — US$8/ha lower	28
Serecon (2001), for Canada in 2000	• Yield — average 10 per cent higher • Variable production costs — 4 per cent higher	28
Corn, insect resistant		
US Department of Agriculture (1999), for the United States in 1998	• Yield — 5–30 per cent higher, according to region • Insecticide applications — significantly reduced	Not estimated
Corn, herbicide tolerant		
US Department of Agriculture (1999a,b), for the United States in 1998	• Yield — changes of –10 per cent to 25 per cent, according to region • Herbicide use — weak evidence of increase	
Cotton, insect resistant		
US Department of Agriculture (1999a,b), for the United States in 1998	• Yield — 0–26 per cent higher (mostly in the range 15–26 per cent), according to region • Pesticide use — 60–85 per cent reductions in most regions	Not estimated
Carpenter and Gianessi (2001), for the United States in 1999	• Yield — average 9 per cent higher • Insecticide use — 17 per cent lower • Insect control costs (technology fee plus insecticide costs) — US$35/ha higher	52
Cotton, herbicide tolerant		
US Department of Agriculture (1999a,b), for the United States in 1998	• Yield changes — weak evidence of changes from –8 per cent to 18 per cent, according to region • Herbicide use — reduced by 23 per cent in some regions	Not estimated
Carpenter and Gianessi (2001), for Tennessee and Louisiana in 1998	• Yield changes — from –7 per cent to 2 per cent, according to variety • Herbicide program costs — reduced for all varieties	From –80 to 335, according to variety

Continued ⇨

3 Benefits from selected genetically modified crops in north America *continued*

Crop type and study	Benefits and costs compared with conventional crops: Description	Estimated gain (loss) US$/ha
Soybeans, herbicide tolerant		
US Department of Agriculture (1999a,b), for the United States in 1998	• Yield — no significant improvement • Herbicide use — changes from – 3 per cent to 51 per cent lower, according to region	Not estimated
Carpenter and Gianessi (2001), for the United States in 1999;	• Herbicide applications — reduced by 12 per cent	Not estimated
Benbrook (2001), for the United States in 1999 and 2000	• Herbicide use — increased • Yields — 5–10 per cent lower • Nitrogen fixation — impaired, especially under conditions of drought or poor soil fertility • Resistance to herbicides — increased	Not estimated
Elmore et al. (2001)	• Yield — 5–10 per cent lower	Not estimated

for soybeans and, to a lesser extent, for cotton. It also found that fewer insecticide treatments were required with insect resistant maize and cotton.

It is a paradox that herbicide tolerant soybeans have been the most successful GM food crop in terms of commercial adoption, but there are doubts about whether this crop type delivers benefits to farmers. Benbrook (2001) says that herbicide use with GM soybeans, under comparable field conditions, is higher than herbicide use for conventional varieties. Benbrook points to evidence from a range of credible sources that yields are 5–10 per cent lower. Contributing to the yield drag may be impaired root development, nodulation and nitrogen fixation — problems that may get worse under conditions of drought or poor soil fertility. Moreover, Benbrook claims, the reliance on GM soybeans is leading to increases in the rate of weed resistance to herbicides. Elmore et al. (2001) also concluded that producers should consider the potential for 5–10 per cent yield differentials between glyphosate (a herbicide) resistant and conventional varieties of soybeans when evaluating the overall profitability of producing soybeans.

There are similar conflicting views in relation to canola. Fulton and Keyowski (1999) found lower returns in Canada for herbicide tolerant canola compared with returns for conventional canola, once the technology fee is taken into account. However, a more up-to-date and comprehensive survey by Serecon

(2001) points to substantially improved returns for herbicide tolerant canola in Canada.

Drivers of innovation and adoption

There is always an incentive to innovate, supported by the forms of intellectual property protection that include plant variety rights and utility patents. Some commentators argue that the ability to patent biological innovations with utility patents represents a strengthening of intellectual property regimes, leading to investment (particularly private investment) in agricultural research and development (US Department of Agriculture 2001a; Rausser 1998).

The market power provided by intellectual property rights gives technology owners the ability to retain at least part of the benefits of their technology, but the owners must also pass on some of the benefits to growers; otherwise, the growers will not adopt. The perceived benefits and patents over the technologies have enabled substantial premiums to be charged for GM seeds over conventional ones (table 4). The commercialised innovations in this area have tended to be focused on the most important crops. In the case of herbicide tolerance, the innovations have tended to favor use of the developers' proprietary herbicides. However, an innovation such as insect resistance has often resulted in less use of the developers' proprietary insecticides.

4 Technology fees for selected genetically modified crops, 1998

Crop	Technology fee
	US$/ha
Potato (NewLeaf®)	74.30
Cotton (BollGard®)	79.26
Maize (various varieties)	24.77
Canola (Roundup Ready®, Canada)	8.87
Soybeans (Roundup Ready®)	17.34

Farmers are on a technology treadmill: they must adopt profitable innovations or face a loss of competitiveness. Government regulatory processes related to environmental impacts are aimed at ensuring that growers are not being forced to adopt technologies that are profitable in the short run but are not sustainable in the long run. The highly competitive nature of agricultural commodity markets means a large proportion of the benefits that technology owners pass on to farmers are passed on to consumers as lower prices. Moreover, the degree of price responsiveness with demand for grain can mean that the effect of technical progress is to reduce returns per unit area to growers (see, for example, Duncan and Tisdell 1971). Thus, the speeding of the innovation process that gene technology enables could contribute to the overall agricultural adjustment process that is reducing the viability of smaller farms.

3

Consumption and market access

The aim in this chapter is to examine:

- the extent to which GM products are making inroads into world food markets;
- the issues of consumer acceptance of food products made from GM organisms; and
- the mechanisms in place to restrict access of GM food products to markets.

As discussed in the previous chapter, the United States is by far the largest adopter of GM foods. Its importance as a food exporter means that many US products made from GM organisms are entering the food channels of other countries.

Consumers in the United States appear to have been largely indifferent to final products made from GM inputs. However, there has been consumer resistance in other countries, particularly in Europe, as consumers become more aware of the existence of these products in the food chain. The main concerns are over the perceived safety of these products as food. However, part of the resistance also appears to be a reaction to (a) possible environmental consequences and (b) the extent of control of the food chain that appears to be being exercised by a relative few companies that own the key technologies that make genetic modification possible.

There seems to be no credible evidence of food safety problems with GM crops that have been released for human consumption. There have been cases of known or suspected allergens (or even toxins) being introduced to plants through gene technology — for example, a hazelnut gene being introduced to an oilseed plant, or a bacterial gene in corn. However, the assessments that new GM plants have to face before they are released for human consumption have ensured that such products do not make it to the market place as a human food. In 2000 a group of world experts concluded that premarketing safety assessments already assure that a GM food is as safe as its conventional counterpart (FAO/WHO 2000). They acknowledged that little is known about the longer term effects of consumption of GM foods, as is the case with any food.

Producers of products that compete in markets with GM ones have tended to fuel food and environmental safety concerns through their marketing strategies. Organic producers, for example, seem to have viewed the introduction of GM foods as a means of boosting demand for their products. The organic industry has an advantage over conventional agricultural industries in this respect because it already has a certification system that can guarantee that products are free of GM inputs.

Consumer resistance may be less if the benefits of GM inputs to consumers are more immediately evident. Only the agronomic benefits of the current generation of GM crops have been stressed. Although benefits are likely to be passed onto consumers through lower prices, this is probably not evident to them. The next generation of GM foods could face less consumer resistance problems because they offer more easily recognisable consumer benefits such as superior taste and colour or improved nutritional composition. However, the recent controversy over a variety of GM corn called Starlink — surfacing around August 2000 — has the potential to harden community attitudes against GM food (see box 3).

3 The Starlink controversy

Starlink is an insect resistant corn that was only released in the United States for feed use, but not food use, because it contains a chemical compound that has similarities to a known allergen. However, it appears Starlink contaminated US food corn supplies through either cross pollination or co-mingling in the handling and storage process. The United States government, in concert with the developer of the seed, announced a recall of Starlink seed and products. No reliable estimates are yet available, but the direct and indirect costs of this recall are likely to be substantial. A containment program by the developer of Starlink identified around 11 million tonnes of corn containing Starlink traces to be redirected to approved uses such as animal feed and industrial processing (Gadsby 2001). In March 2001 the US government announced it would spend about US$20 million to purchase US corn seed suspected of containing Starlink genetic material.

Because Starlink is not approved for feed or food use in Japan, it has disrupted the US exports of corn to that country (Lin, Price and Allen 2001). Testing and identity preservation procedures to ensure US corn exports do not contain Starlink are adding an estimated US$3–7 a tonne to the cost of shipping US corn to Japan. Concerns over Starlink are spreading to the other key grain importing countries such as the Republic of Korea and Chinese Taipei (Lin, Price and Allen 2001).

Consumer surveys

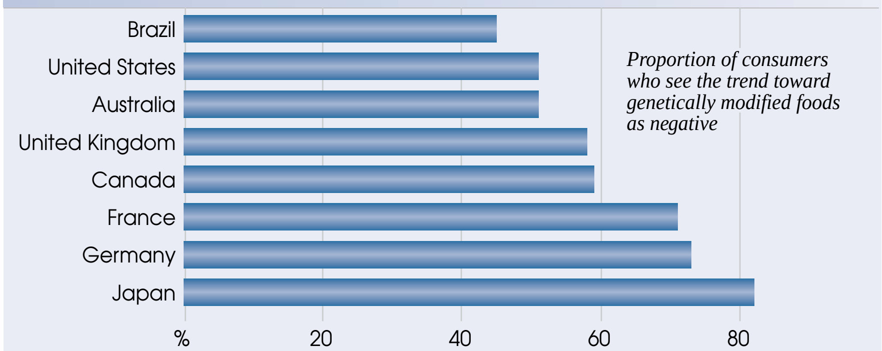
Many surveys have been undertaken to ascertain consumer attitudes to gene technology and GM food. The US Department of Agriculture (2001a) reported a comprehensive review of these surveys.

A June 2000 survey covering a number of countries reported in Angus Reid Group (2000) is fairly typical of the surveys. It shows that over half of consumers in all but one of the surveyed countries view the trend towards GM food as a negative one (figure G). Between 44 per cent and 58 per cent of these consumers — depending on the country — say they still understand only a little about GM foods. The understanding is greatest in Germany, Australia and the United Kingdom, and lowest in the United States and Brazil.

Consumer attitudes appear to be hardening against GM products, even in north America where consumption of GM grains has been very large. According to Angus Reid Group (2000), US consumers with negative views grew from 45 per cent of the population in 1998 to 51 per cent in 2000. The trend is even more pronounced in Canada — 59 per cent of consumers in 2000 held negative views about GM foods, compared with 45 per cent in 1998.

However, according to Biotechnology Australia (2001), studies in Australia that have tracked consumer attitudes over time suggest that Australian consumers are becoming more accepting of GM products. Government agencies such as Biotechnology Australia have been attempting to influence consumer attitudes to gene technology in Australia by providing them with access to balanced and factual evidence on its risks and benefits.

G Consumer attitudes to genetically modified foods



Source : Angus Reid Group (2000).

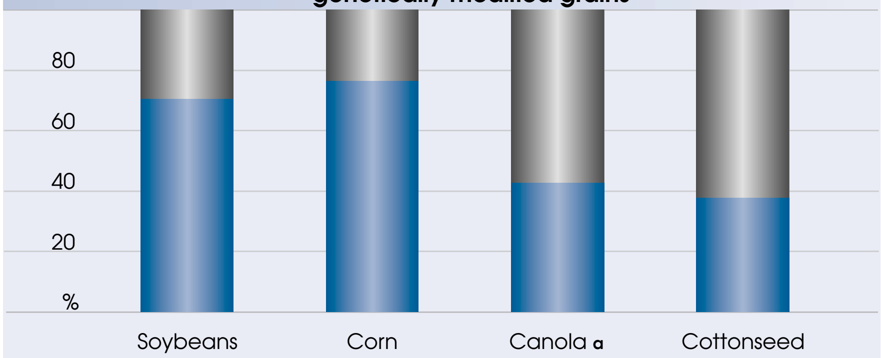
It may be that there is a cycle in which concerns grow as consumers become aware of the prevalence of GM products in the food chain, but then concerns diminish as knowledge about gene technology increases. There can also be a marked difference between what consumers say about their concerns in response to surveys and how they act on those concerns in the market place. One indication of this is the substantial market penetration by GM foods. Another indication is that there is also only limited evidence of premiums for non-GM grain and oilseeds in world markets. (This is discussed in more detail in chapter 9.)

Market penetration

Despite consumer acceptance issues indicated by surveys, GM products have made substantial market inroads. Lococo (2001) says that the Grocery Manufacturers of America estimates that more than 60 per cent of food in US supermarkets contains GM ingredients. The types of crop that have been genetically modified are important in world markets for vegetable oil and animal feed stuffs (see appendix A).

Soybeans and canola provide around 45 per cent of the world's edible oils and 75 per cent of the vegetable protein meals that are usually fed to livestock. (With oilseed crops, meal is a byproduct of the crushing process that produces the oil.) Corn (or maize), the only non-oilseed grain that has been genetically modified, accounts for nearly 60 per cent of world consumption of grain for livestock feed. It also makes up about 15 per cent of world consumption of grains for food and industrial uses.

H **Shares in the world grain trade of countries that produce genetically modified grains**



a Including intra-European Union trade

The countries that produce GM crops are important in world trade in grains and oilseeds (figure H). At this stage, the crops in these countries are generally not separated into GM and conventional groups in the bulk handling systems. Therefore, the total supplies they deliver to world markets may be considered as potentially containing some GM material for all practical purposes.

According to the US Department of Agriculture (2001b), US corn exports were reduced in 2000-01 because some importers (especially Japan and the Republic of Korea) are trying to minimise purchases of unapproved varieties of corn, most notably Starlink corn or corn contaminated with Starlink. These importers have reportedly been willing to pay a premium for corn from alternative suppliers such as South Africa, Argentina, China and Brazil (USDA 2001b).

The GM status of US corn, or the possibility that approved corn varieties could contain detectable quantities of unapproved GM varieties, has also contributed to the EU market largely diminishing as a destination for US corn (Paarlberg 2001). US corn exports to Europe declined from an average 2.8 million tonnes in the five years to 1995-96 (the first year in which GM corn was marketed) to 141 000 tonnes in 1999-2000.

There are emerging indicators that that GM feed grains and meals may lose ground to non-GM materials because there is consumer resistance to products from animals fed GM material (although studies show that these animal products do not contain any of the modified DNA). In January 2001, for example, three major supermarket chains in the United Kingdom announced that they were removing such products from their own brand lines.

There are also signs that non-GM soybeans, particularly from Brazil, are preferred over US soybeans in some key grain markets. In late 2000 and early 2001 the Republic of Korea filled a number of 25 000–50 000 tonne tenders for specified non-GM soybeans.

Market access restrictions or conditions

In response to perceived safety concerns, a number of countries implemented measures restricting access to their markets. These include import restrictions on sanitary and phytosanitary grounds, and the introduction of technical requirements such as labeling. The key market access restrictions are listed in table 5. The agreements relevant to world trade in GM organisms are outlined in box 4.

4 International agreements relevant to trade in genetically modified organisms

A number of agreements under the World Trade Organisation arrangements are important influences on the pattern of world trade in GM products.

- The Agreement on Sanitary and Phytosanitary Measures (SPS) establishes the circumstances under which a country may refuse access to its domestic market on the grounds of risks to the environment and to human and animal health.
- The Agreement on Technical Barriers to Trade (TBT), covering issues such as packaging, marking and labeling requirements, seeks to ensure technical regulations do not create unnecessary obstacles to trade.
- The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) is aimed generally at protecting intellectual property rights. The apparent reason for this protection in trade arrangements is that nonrecognition of intellectual property rights represents a nontariff barrier to trade, in that exporters will be less willing to export their products to countries where pirating of their technology can occur (Lesser 1997).

Member countries of the World Trade Organisation are encouraged to use existing international standards, guidelines and recommendations; usually, the World Trade Organisation does not develop these standards.

- International food safety and labeling standards are based on those developed by the Codex Alimentarius Commission (a joint Food and Agriculture Organisation/World Health Organisation undertaking).
- For plant health, the standards are based on the Food and Agriculture Organisation's International Plant Protection Convention; for animal health, the standards are based on the Office International des Epizooties.
- For intellectual property rights, the starting point is the main international agreements of the World Intellectual Property Organisation (WIPO) that already existed before the World Trade Organisation was created. The TRIPS agreement adds a significant number of new or higher standards where it is thought that the WIPO agreements do not provide adequate coverage.

The Biosafety Protocol of the United Nations Convention on Biological Diversity is an international agreement between member countries of the United Nations Convention on Biological Diversity. It sets the rules for movements across borders of living GM organisms that may affect the conservation and sustainable use of biodiversity. After five years of negotiation, the text of an agreement — the Cartagena Protocol on Biosafety — was agreed in Montreal in January 2000. It will enter into force for its members following ratification by fifty countries, a process that Hillman (2000) estimates will take approximately two years. The protocol is discussed in greater detail in a later chapter of this report.

5	Key market access conditions or restrictions for genetically modified crops
Sanitary and phytosanitary	
European Union	The European Union does not allow the import of GM products apart from three varieties of insect resistant maize (another three varieties grown in the United States do not have approved status), one variety of herbicide tolerant maize and all varieties of herbicide tolerant soybeans.
Sri Lanka	Effective from 1 September, all imports of GM food are banned. Certification that a food import is free of GM material is required.
Mandatory labeling	
Australia	Standard A18 of the Australian Food Standards Code requires labeling of all GM food and ingredients, apart from that prepared for immediate consumption (such as restaurant and takeaway food) and highly refined foods where the novel DNA or novel protein has been removed. A tolerance of 1 per cent is allowed for accidental presence of GM material.
European Union	EU regulation 1139/98 requires that foodstuffs derived from GM soybeans and corn be labeled. Subsequent EU regulations 49 and 50/2000, which came into force in April 2000, establish that materials derived from GM organisms (either ingredients or food comprising a single ingredient) are exempt from labeling when they make up less than 1 per cent of the material.
Japan	From 1 April 2001 Japan requires labeling of 24 foods made from corn and soybeans, including tofu, corn snacks and natto (fermented soybeans), but only if the GM component makes up more than 5 per cent of the material. Oils and other highly processed foods made with genetically modified ingredients could be excluded from the list because current testing procedures cannot verify GM content.
Republic of Korea	From 13 July 2001 all products containing GM products as a ‘major input’ are required to be labeled, except where the final product does not contain foreign protein or recombinant DNA (that is, they are removed during processing).
	From 1 March 2001 unprocessed soybeans and corn produced through biotechnology will have to be labeled. The tolerance level for adventitious contamination will initially be set at 3 per cent but could be reduced to 1 per cent in the future.
Russian Federation	Effective from 1 July 2000 all food and medical products derived from GM sources must be labeled, except where these foods do not contain the modified protein or recombinant DNA (as can happen with oils derived from GM plants, for example).

There is a trend towards mandatory labeling of products containing GM organisms on the grounds that labeling enables consumers to make more informed decisions (table 5). Countries that have introduced mandatory labeling, or have flagged their intentions to introduce it, include Australia, the European Union, Japan, New Zealand, the Republic of Korea, the Russian Federation and Thailand. As discussed in the next chapter, this labeling requirement can be a significant barrier to world trade because it can impose higher costs on suppliers of GM organisms. These costs can spill over to suppliers of conventional products.

The United States requires labeling only if the GM product is substantially different from its conventionally bred counterpart. In early 2001 the Food and Drug Administration was developing guidelines to assist food manufacturers who wish to voluntarily label their products as being made with or without GM inputs.

In the near future the European Union is likely to extend mandatory labeling to animal feedstuffs containing GM inputs. To facilitate its mandatory labeling regime, traceability requirements on GM products have also been flagged for the European Union. Traceability would require elaborate record keeping and possible segregation of GM products throughout the production process and may pose a substantial technical barrier to trade.

4

Identity preservation and price premiums

Identity preservation

Identity preservation is the collective term for arrangements that ensure that the integrity of product — in this case, grains — is not adversely affected through co-mingling with other grain or products. Given the consumer acceptance problems with GM grains and possible price premiums for certified non-GM grains in world markets, the aim of identity preservation arrangements in the grain industry is to prevent mixing of conventional grains with GM varieties. However, as grains are increasingly genetically modified to enhance quality characteristics, the arrangements are likely to become aimed at preserving the quality of the modified grain. These arrangements are already well developed with high value grains such as high oil corn or high protein soybeans.

With grains, cross pollination in the field and co-mingling in the handling, storage and transportation process can result in the presence of GM material. Identity preservation, therefore, requires a whole supply chain approach.

At the production stage, identity preservation involves establishing separation distances between conventional and GM varieties. The separation distance depends on pollination factors such as whether the plant is open pollinated or self pollinated, or whether the pollen is borne between plants by insects or wind.

At the handling, storage and transportation stage, identity preservation costs are related to mainly losses in effective storage and transportation capacity through segregation requirements, loss of size economies, and the increased need to clean facilities between different grain handling tasks. To reassure buyers that quality requirements are being met, identity preservation arrangements typically involve elaborate documentation and testing regimes.

A number of recent incidents illustrate the difficulty of preventing the presence of GM material, either through cross pollination or adventitious mixing in the grain handling system. Starlink corn made up less than 1 per cent of total US corn plantings in 1999 and 2000 but in 2000–01 traces of its unique genetic material were found in around 11 million tonnes of corn, equivalent to about 4 per cent of annual US corn production (Gadsby 2001). There have been other smaller incidents: for example, in April 2001 in Canada, a variety of GM canola seed (Quest) was recalled after it was found to contain genetic material from another strain of GM canola that was not approved for export.

GM crops, particularly those without altered quality traits, can pose special problems because their differences from their conventional counterparts are not immediately obvious. This can require costly testing procedures or comprehensive documentation throughout the supply chain.

The two main tests for the presence of GM material are the PCR test (polymerase chain reaction) that detects modified DNA and the ELISA test (enzyme linked immunosorbent assay) that detects the unique proteins produced as a result of the genetic modification. According to the Economic Research Service (2000), a PCR test takes two to ten days and costs US$200–450. The more elaborate form of the ELISA test takes two hours and costs up to US$10, while a simpler ELISA dipstick test provides a ‘yes–no’ result in five to ten minutes at a cost of US$3.50. Usually, a different ELISA test is required for each genetic modification. PCR tests are more commonly used than ELISA tests at subterminals and export elevators because they are more sensitive and one set of tests can be used to detect the presence of a range of genetic modifications (Economic Research Service 2000).

Neither PCR nor ELISA tests can detect some processed products derived from GM crops — for example, oil derived from herbicide tolerant canola — because the processing has removed the modified DNA or the unique protein.

Customer tolerances for the presence of GM material can differ. An important influence on these tolerances is likely to be the labeling requirements, for which countries have different standards. These requirements range from labeling for 1 per cent content for the European Union, up to labeling for 5 per cent content for Japan (table 5). It seems reasonable to expect an inverse relationship between the tolerance level and the cost of identity preservation; that is, the lower the tolerance level for GM material, the greater the cost of identity preservation is likely to be.

Because marketers of GM crops could be held liable for any accidental mixing with other grains in the handling storage and transportation system, identity preservation costs could also include a component to compensate marketers for the risks assumed.

There is now a substantial literature on the costs of segregation and identity preservation to do with GM grain, including Buckwell, Brookes and Bradley (1998), Bullock, Desquilbet and Nitsi (2000) and the Economic Research Service (2000). This literature generally suggests, for a mixed production system of conventional and GM grain, that identity preservation in terms of certifying non-GM status adds 5–15 per cent to the cost of grain delivery.

In a central bulk handling and transportation system for grain, there are complex issues about how costs should be apportioned to the tasks of handling the different crop types. In its 2000 Budget, the Australian government committed $3.65 million over four years to establish a program to assess the requirements and costs of segregating products developed with gene technology and ensuring these products can be traced through to their origins.

The United States, Canada and Argentina undertake only limited segregation of their crops into conventional and GM grain. Around half of the US soybean crop and the Canadian canola crop are genetically modified, so there is considerable scope for the creation of additional supplies of identity preserved grain.

Premiums for non-GM crops

A premium for certified non-GM grain over equivalent GM grain will arise where available quantities of non-GM grain are relatively restricted in relation to demand for this type of grain. That is, the price for non-GM grain must rise to ration use and to bring forth additional supplies.

In the short run, the extent to which the price for certified non-GM can rise in relation to mixed grain or GM grain is limited by the cost at which new certified non-GM supplies can be created through identity preservation arrangements. In the longer run, the premium will reflect a combination of identity preservation costs, the degree of substitutability in consumption and the difference in production costs of conventional and GM grain.

Evidence of premiums or discounts

A September 2000 survey by the American Corn Growers Foundation found that 30.5 per cent of grain elevators in the United States required or suggested segregation of GM and non-GM corn. Around 22 per cent of elevators were actually paying premiums for non-GM corn of US10–35 cents a bushel — around 4–15 per cent higher than the price for GM corn.

A January 2001 survey of prices paid for corn and soybeans in the midwest cash grain market in the United States showed that conventionally bred corn and soybeans were commanding premiums of US$9 a tonne and US$5 a tonne respectively over GM varieties (Wulf 2001).

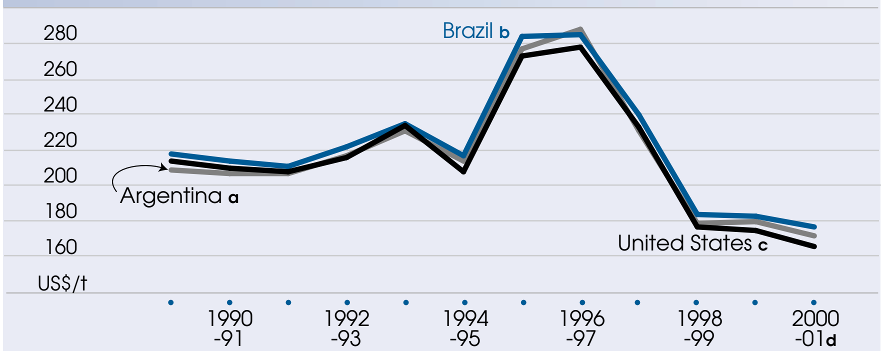
A futures contract for non-GM soybeans that began trading in Japan in May 2000 has averaged a 5–8 per cent premium compared with the equivalent conventional soybean contract.

There are reports that Brazil's largest soybean crusher, Ceval, plans to use certified non–GM soybeans for 20 per cent of its crush in 2001-02, compared with just 5 per cent in 2000-01. (Brazil does not allow the use of GM soybeans but some consider that there is fairly extensive illegal use.) Ceval is reported to not expect, at this stage, to gain a premium for the certified GM-free product.

There is some evidence that the Brazilian soybean prices have increased compared with US soybean prices in recent years (figure I). However, it is difficult to attribute this widening to demand for non-GM soybeans, because the Argentinian (a GM producer) price margin has also increased.

The European Union market could be paying premiums this year for imports of non-GM canola, following their relatively poor canola/rapeseed crop in

I **Soybean indicator prices, by key soybean exporting countries**



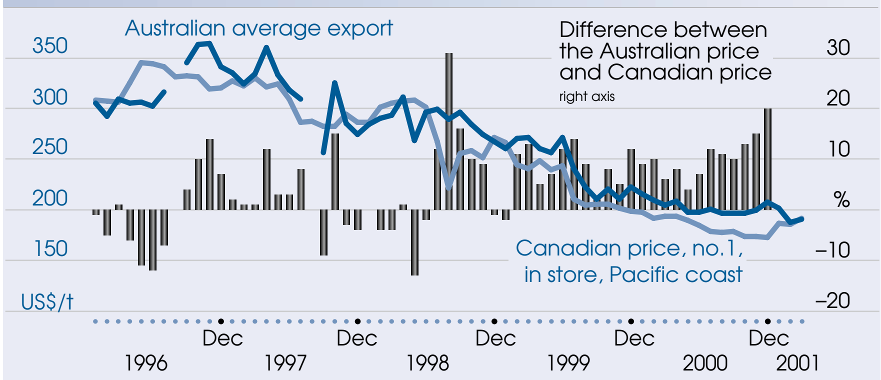
a Safras and Mercado, fob Buenos Aries. **b** Safras and Mercado, fob Rio Grande. **c** US no. 1 yellow, Central Illinois. **d** Eight months only.

2000. As the main source of export availabilities of non-GM canola, the Australian grain industry would be the main beneficiary of these premiums. (The European Union does not approve GM canola from Canada for importation.) For example, it was reported in August 2000 that European buyers paid what amounts to a US$5 a tonne premium on a 150 000 tonne cargo of Australian (non-GM) canola (Reuters, 20 August 2000). Portmann and Tucek (2001) say that over 30 per cent of Western Australian canola production in 2000-01 will be sold to the European Union market at premiums of around $10 a tonne.

The tendency for the Australian canola export price to strengthen compared with the Canadian canola price in recent years (figure J) is generally consistent with increasing consumer demand for non-GM canola. However, other factors, such as increased reliability of Australian canola supplies, may also have contributed to the strengthening of the export price. Changes in quality factors (including oil, protein and glucosinolate concentrations) with these two countries' canola crops over the period in question are not consistent with such a strengthening.

To some extent, consumer preferences for non-GM food may be indicated by other than market premiums and discounts. The strong recent worldwide growth in demand for certified organically produced foods may at least partly reflect that some consumers are increasingly willing to pay premiums for products with their identity preservation certified. (Typically, organic standards preclude the use of GM organisms.)

J **Canadian and Australian canola prices**



Another possible manifestation of consumer preferences may be in relation to stock changes for GM grains. Canada accumulated unprecedentedly large stocks of canola over the past few years, at a time when the other key exporters of non-GM canola, including Australia, were able to dispose of most of their supplies. However, Canadian marketers claim that factors other than the GM status of the Canadian canola crop are causing this buildup (Bernard Badani, Deputy Director, Export Market Division, Agriculture and Agri-Food Canada, personal communication, 20 October 2000). One important factor is the rapid rate of growth in canola production in recent years (to record levels) and the consequent logistics problems. Canada is forecast to draw down its canola stocks by around half over the 2000-01 marketing season.

The nature and extent of premiums and discounts in the market suggest markets remain in a price discovery phase. Processors and marketers are trying to establish whether consumers are willing to pay premiums for grain and grain products that are certified to not contain GM material. The picture will continue to become clearer over the remainder of 2001 as the new north American corn, canola and soybeans crops are brought to market and as mandatory labeling regimes for GM products come into force in many countries.

5

Market implications of the current generation of GM grains

In the preceding chapters, the production and consumption dimensions of the most important gene technologies relevant to broadacre cropping were outlined. The aim of this chapter is to assess the market implications of the current generation of GM grain crops in relation to:

- the possible impacts of these technologies on world prices for key agricultural commodities and on patterns of world production and trade;
- the implications of these technologies for owners of the technologies, producers and consumers; and
- the likely impact of these technologies on Australian grain prices and production.

Modeling framework

The AGLINK model (see box 5) was used to assess the range of economically relevant effects of the use of GM crops. The direct factors associated with GM crops that need to be considered in this analysis are agronomic factors (such as yield and input costs), quality factors (such as altered oil profiles) and market access restrictions or conditions (such as import restrictions on GM products). Indirect effects (externalities) of the use of these GM crops are also possible, such as adverse effects on the environment.

There is a growing body of literature on quantitative assessments of the market impacts of GM crops. These include assessments of soybeans (Moschini, Lapan and Sobolevsky 1999; Moschini 2001), canola (Mayer and Furtan 1999), cotton (Traxler and Falck-Zepeda 1999) and all GM crops (Foster 1999a, 2000, 2001).

The AGLINK model is particularly suited to assessments of the current generation of GM crops because it contains a detailed representation of the markets for livestock, rice, wheat, coarse grains and oilseeds. The oilseeds submodel includes explicit representation of the oilseeds, oil and oil meal components of the market for soybeans, canola (rapeseed) and cottonseed. However, cotton production — the source of cottonseed — is exogenously determined.

5 AGLINK model – a brief description

AGLINK is a multicommodity, multicountry/region econometric model of world agriculture. The Secretariat of the Organisation for Economic Cooperation and Development (OECD) developed the model in close cooperation with member countries of the OECD.

The model is based on annual data and represents the dynamics of supply and demand for a range of commodities important to the OECD policy making environment — namely, wheat, rice, coarse grains, oilseeds, oilseed meals and oils, milk and dairy products, and meat and eggs. Market prices are determined through a global supply and demand equilibrium.

AGLINK is a partial equilibrium model in the sense that nonagricultural markets are not modeled. A limitation of AGLINK at this stage is that agricultural markets for cotton, sugar, sheep meat, fish and wool are7 not yet modeled or are incompletely modeled.

The model consists of complete modules for seven OECD countries/regions: Australia, Canada, the European Union (fifteen countries), Japan, Mexico, New Zealand and the United States. There are also model representations for non-OECD countries that are important in world trade in agricultural commodities. These include Argentina and China, for which there are detailed modules. There are less detailed representations for Brazil, the Czech Republic, Hungary, Paraguay, Poland, Slovakia, Chinese Taipei and the countries of the former Soviet Union (as a bloc). The remaining countries are aggregated into a rest of world module.

Many of the supply and demand relationships in AGLINK are partial adjustment processes — that is, the full impact of a supply or demand shock takes a number of years to flow through. To allow for this, results are reported for the end of the assessment period — that is, 2010. As well, the results are reported as changes from a baseline set of projections. ABARE developed baselines for all variables in the model; the first five years of this baseline reflect the projections reported in ABARE (2001).

Assumptions

Farm level assumptions

The assumptions about the agronomic benefits of the various crops are judgments broadly based on the review reported in table 3. Data on US costs of production for corn, soybeans, cotton and dairy were obtained from US

Department of Agriculture (2000). Changes in production costs take into account the technology fees shown in table 4.

The key farm level assumptions underlying the analysis are summarised in table 6.

Market access assumptions

It is possible to restrict trade flows in AGLINK to reflect import bans. This method can be used to represent the inability to import Canadian canola (which is not segregated) into the European Union. Often, a producing country may be able to segregate its crops into conventional and GM components, so trade flows are not affected. However, the segregation requirement

6 Key modeling assumptions

Yield and production cost effects	Adoption a
Soybeans, herbicide tolerant	
• 1% yield increase	63% in the United States and
• 4% decrease in cost of production, arising from savings on herbicides	90% in Argentina
Maize, herbicide tolerant	
• 7.5% yield increase	7% in the United States
• 3% increase in cost of production, despite savings on herbicides	
Maize, insect resistant	
• 7% yield increase	18% in the United States
• 1.5% increase in cost of production, despite savings on insecticides	
Canola, herbicide tolerant	
• 10% yield increase	60% in Canada
• 4% increase in cost of production	
Cottonseed, from herbicide tolerant cotton	
• 5% yield increase	44% in the United States
• 5% increase in cost of production, despite savings in herbicides	
Cottonseed, from insect resistant cotton	
• 9% yield increase in the United States	25% in the United States,
• 3% reduction in US cost of production due to savings on insecticide	33% in Australia

a Proportion of total area planted.

can increase costs by requiring GM and conventional product to be separated in the handling, storage and marketing system, so export supply equations are adjusted to reflect these additional costs. Similarly, product labeling requirements can add to supply costs because they require increased segregation at all levels of the marketing chain. There are also the monitoring, verification and compliance costs of administering any labeling regime, which are probably higher if the labeling requirement is mandatory.

The assumption with this analysis is that export offer prices for each type of GM grain from the United States and other GM-producing countries are increased by 10 per cent to any market where identity preservation for labeling purposes is required. The countries that require mandatory labeling are so important in the world grain trade that this would imply almost complete segregation of these countries' exports into GM and non-GM product. It is assumed that identity preservation costs of this magnitude are incurred with all Australia's exports of cottonseed (of which around one-third is genetically modified).

Adoption rates and technology fees

The adoption rate with a GM technology is likely to depend on the profitability, which depends on the price received for the output of the crop. It was beyond the scope of this analysis to incorporate a relationship between prices and adoption rates. Instead, it simply assumes that the adoption rates for each crop technology are maintained at 2001 rates throughout the assessment horizon.

The technology fees that can be charged to growers could also be expected to vary with market prices. Again, for the purposes of this analysis, it is assumed that technology fees are maintained at 2001 levels throughout.

Discussion of model results

The key results from the AGLINK simulations are summarised in table 7. The extent to which these impacts flow through to Australian producers is also reported in this table.

No market access restrictions

The effect of adoption of the GM technologies is to substantially lower world grain prices (table 7). Prices are estimated to be around 2.4 per cent lower

6 Market dynamics of a cropping innovation

An innovation in the broadcare cropping sector sets in train complex adjustment processes in grain and livestock markets. Broadly, an innovation can increase the profitability of growing a particular crop by reducing input costs, increasing yields or improving quality (or some combination of these).

At the aggregate level, the increased profitability means that production of that crop is increased at the expense of other crops (or livestock) that compete for available cropping land. It can even mean an expansion in overall cropping area because it enables cropping to move into regions that were not previously viable.

At the individual grower level, it can mean that adopters of the innovation expand production at the expense of the nonadopters. In competitive markets such as the grain market, the overall effect is that the offer price for the product of that crop is lowered, reflecting the lower per unit cost of production.

Because processors and end users of the innovative product can get it at a lower price, this means higher use of the product and displacement of substitutes for this product in consumption. For example, an innovation that lowers the cost of corn production will mean that more corn is used in feed rations at the expense of other feed grains such as sorghum. However, sources of protein for animal feed rations such as soymeal may be complements with feed grains, so consumption of these complements may increase.

Where a country is also an exporter, the lower production cost arising from an innovation means that the country expands its share of the export market at the expense of nonadopting countries that produce competing products. The change in price relativities can also change production mixes in these importing countries.

Market access restrictions by some countries related to GM crops can require separation into GM and non-GM supplies at the export position of the supplying country. The additional costs of this separation flow through to increase the world price of both products. These additional costs on exports increase the profitability of using grain domestically rather than exporting it, thus reducing exports.

7 Estimated market impacts of genetically modified crops, 2010

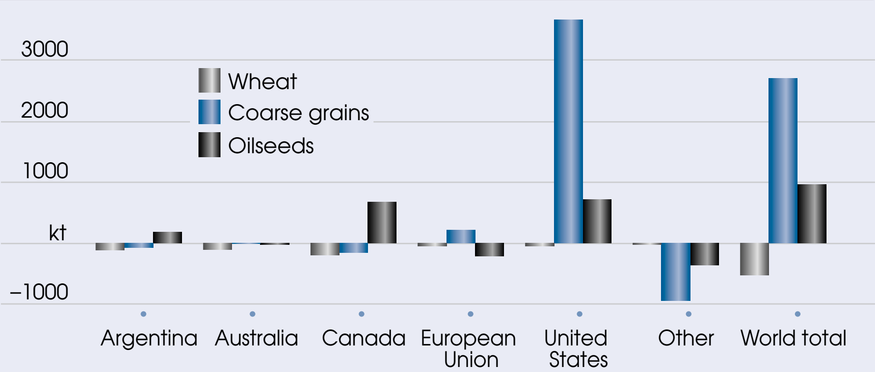
	Grain			Livestock		
	Wheat	Coarse grains	Oilseeds	Beef	Pig meat	Poultry meat
	%	%	%	%	%	%
Without market access restrictions						
World						
Indicator price **a**	–0.8	–2.4	–2.1	–0.7	–1.2	–0.8
Production	–0.1	0.3	0.4	–	0.1	0.3
Exports **b**	–	3.1	4.3	–	–	–
Australia						
Producer prices	–0.7	–1.3	–1.7	–0.7	–0.9	–0.8
Production	–0.4	–0.1	–1.0	–0.7	0.4	0.1
Gross value	–1.1	–1.4	–2.6	–1.4	–0.6	–0.6
With market access restrictions						
World						
Indicator price	–0.3	2.7	2.3	–1.1	–2.0	–1.7
Production	–	0.1	0.2	0.3	0.3	0.4
Exports **a**	1.3	–4.7	–11.8	–	–	–
Australia						
Producer prices	–0.2	2.8	2.1	–1.1	–1.5	0.3
Production	–0.4	1.2	2.3	–1.3	–2.7	–0.1
Gross value	–0.7	4.0	4.5	–2.4	–4.2	0.2

a Indicator prices are US export prices. **b** Argentina, Australia, Canada, European Union and the United States. – Negligible, less than 0.05.

for coarse grains and 2.1 per cent lower for oilseeds. This fall reflects the impact on supplies of increased productivity due to crop innovations. While wheat innovations were not modeled, wheat prices decline in response to increased competition from coarse grains and oilseeds.

Reflecting changes in relative returns, world production of coarse grains and oilseeds increases while wheat production declines marginally (figure K). These results suggest a pronounced shift in comparative advantage in grain production in favor of those countries adopting the new technologies. That is, coarse grains and oilseed production rises in the United States, as does oilseed production in Argentina and Canada. Generally, where a country does not adopt a particular innovation, its production of that crop declines. The main exception is the European Union, where there is an increase in coarse grain production. This is because the combination of government

K Change in the pattern of world grain production, 2010
No market access restrictions

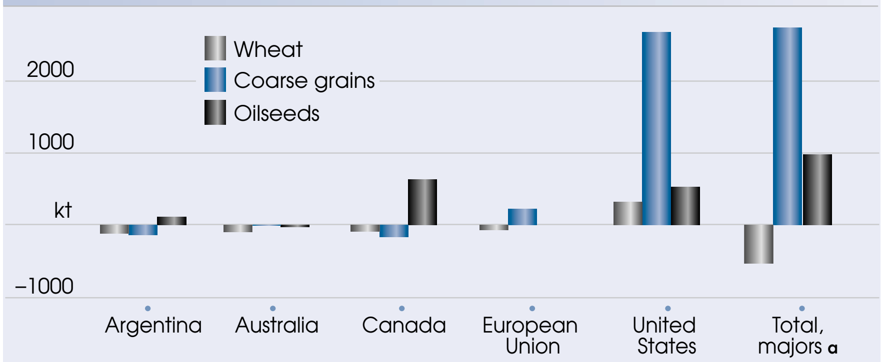


support levels and changes in grain price relativities favors a shift to coarse grain production at the expense of production of oilseeds and wheat.

These changes in comparative advantage are reflected in world trade in grains. The United States increases its share in world trade for all grains and Canada increases it share of the world canola trade, while Australia, the European Union and some other countries lose market share (figure L). Overall, world trade in coarse grains and oilseeds increases but wheat trade declines slightly (table 7).

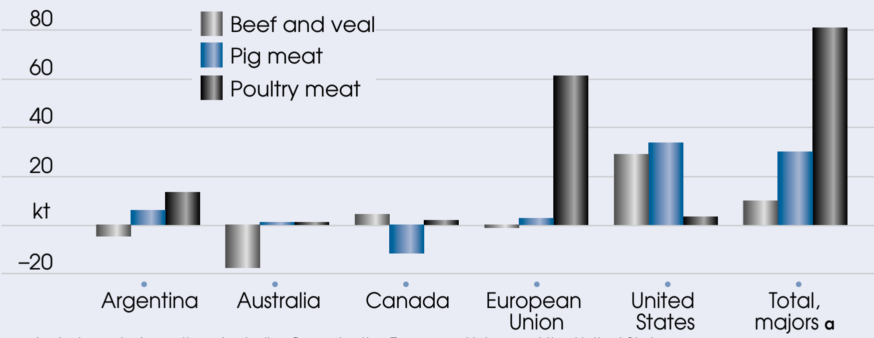
The benefits of the innovations could be expected to spill over to sectors that use grains, particularly the meat sector where grains and oilseeds and the meals derived from them are used as feed. The modeling results show that

L Change in the pattern of world grain exports, 2010
No market access restrictions



a Includes only Argentina, Australia, Canada, the European Union and the United States.

M Change in the pattern of world meat production, 2010
No market access restrictions



a Includes only Argentina, Australia, Canada, the European Union and the United States.

the lower grain and oilseed prices lead to slightly higher meat production and lower meat prices (table 7). There is a negligible impact on world dairy production. Export prices for dairy products are slightly lower — the largest decline being nearly 1 per cent for butter. The price declines reflect lower production costs due to lower feed costs.

The model results suggest that some slight changes in comparative advantage in meat production are likely as a result of the decline in feed costs, particularly towards the United States (figure M). Australia produces slightly less beef and veal because its largely grass fed production system is made slightly less profitable compared with the more grain intensive systems of its competitors in the world meat market.

Distribution of benefits

The benefits of these technologies are likely to be distributed among owners of the technologies, grain producers and consumers of grain products. The benefits to consumers can be estimated based on the concept of consumer surplus that is explained in Varian (1987).

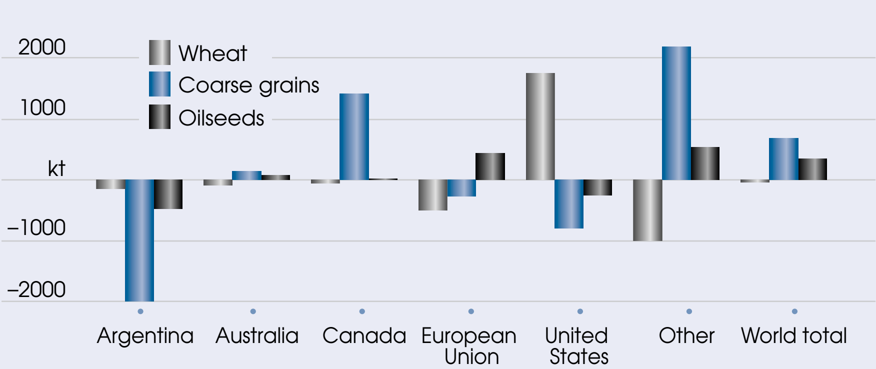
The main beneficiaries are overwhelmingly consumers, but significant benefits also accrue to the owners of the technologies. The adopters of the technology would gain while the nonadopters would lose. At the world level, consumers of coarse grains and oilseeds benefit by around US$5.2 billion a year (in constant 2001 US dollars). Note that this ignores any potential ‘alleged’ consumer costs of consuming GM crops.

With market access restrictions

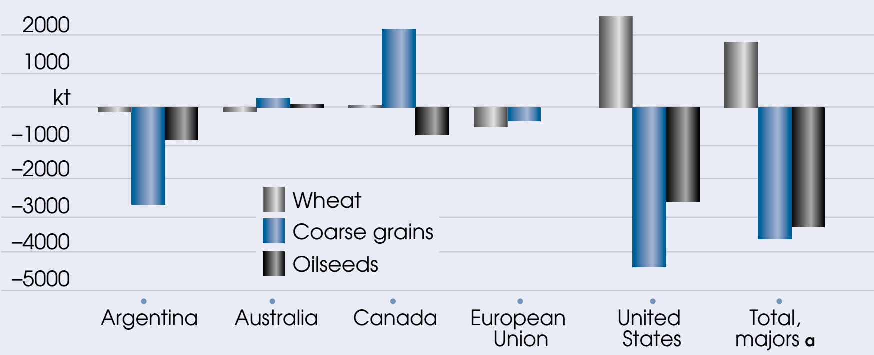
Accounting for the additional costs of delivering identity preserved grain to markets that require it, world export prices for grains and oilseeds increase rather than decline, as would occur without market access restrictions (table 7). As an example, the 2.1 per cent reduction in the world oilseed indicator price that would have resulted without the identity preservation requirement now becomes a 2.3 per cent increase. The additional costs mean that comparative advantage in grain production is no longer shifted toward the United States (figure N).

Instead, the comparative advantage in coarse grains shifts towards Australia and the 'Other' group of countries (including a major non-GM grain producing country, Brazil). The United States loses share in world export markets

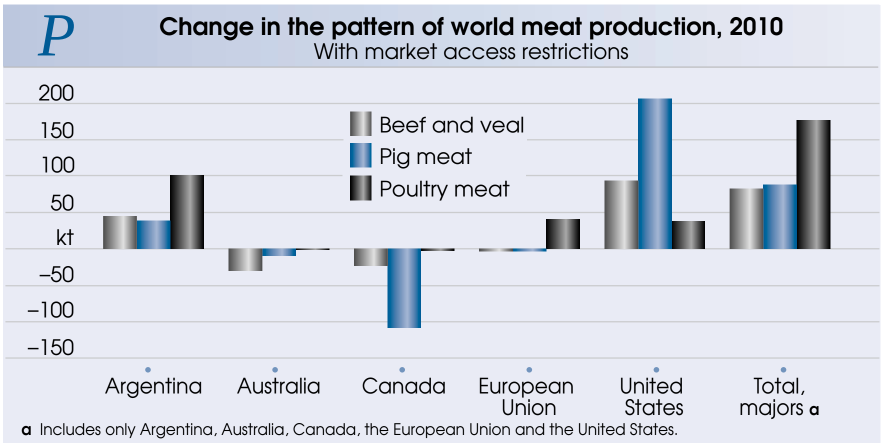
N **Change in the pattern of world grain production, 2010**
With market access restrictions



O **Change in the pattern of world grain exports, 2010**
With market access restrictions



a Includes only Argentina, Australia, Canada, the European Union and the United States.



for coarse grains and oilseeds but gains with wheat (figure O). US wheat exports increase mainly because increased supplies of corn and oilseeds are directed to the domestic US market and these displace some wheat in animal feed rations.

Compared with the 'no market access restrictions scenario', comparative advantage in livestock production shifts away from countries that are assumed to require segregation of GM grain because of the cost disadvantage that this incurs (figure P).

Market access restrictions elsewhere mean an increase in the benefits received by consumers of US grains of around US$1.5 billion. However, in aggregate, consumers of coarse grains and oilseeds in the rest of the world are worse off by around US$6 billion a year (in 2001 dollars), compared with the situation in which there are no market access restrictions.

It should be noted that the reduced profitability implied by market access restrictions would probably lead to pressure to reduce technology fees.

6

Case study: GM canola in Australia?

Australia has trialed different forms of GM canola and one particular form — herbicide tolerant canola — is nearing commercialisation. In this chapter, the nature of world and Australian developments with GM canola are reviewed and some aspects of the economic viability of herbicide tolerant canola in Australia are assessed.

Canola developments

As discussed earlier, canola is the third most field trialed of the GM crops in the world after corn and potatoes. Based on OECD (2001), the main trials of GM canola have been in Canada (47 per cent of total world field trials), the European Union (29 per cent) and the United States (20 per cent).

8 Key forms of genetically modified canola in the pipeline

Developing company/institution	Trait(s)
University of Chicago	Insect (lepidopteran) resistance
Cargill	Fungus resistance (cylindrosporium, phoma, sclerotinia)
Calgene	Agronomic properties — yield increased
Calgene, Monsanto	Oil profile altered to be high in stearates. Does not require hydrogenation thus reducing processing costs
Calgene, Cargill, Du Pont	Oil profile altered to be very low in terms of saturated fatty acids.
University of Calgary, Rhone Poulenc Canada	Anticoagulant gene inserted, enabling pharmaceutical production.
Calgene	Altered oil profile with enhanced medium chain fatty acids and triglycerides, aimed at providing less expensive sources of raw materials for nutritional formulas and high energy foods
Limagrain, Plant Biotechnology Institute, Pioneer Hi-Bred International, University of Calgary	Altered nutritional qualities
AgrEvo	Male sterile, fertility altered

Genetic modification of canola has largely been focused on herbicide tolerance and product quality (figure D). With product quality, the aim has been mainly to alter the oil profile so it is higher in two particular acids — stearic and lauric acid — and lower in saturated fats. A canola oil that is higher in stearic acid enables the manufacture of a solid canola product, such as a margarine, without extensive hydrogenation. A high laurate acid oil is suited to such food applications as confectionery coatings, frostings and icing.

In some cases, canola varieties are being sought that also have 'super high' levels of erucic acid, of which a key use is to produce erucamide (a slip agent in the manufacture of plastic films). (Canola was developed to have *lower* erucic acid levels than the traditional rapeseed from which it was bred.)

9 Field trials of genetically modified canola in Australia

Company	Year (no. of trials)	Trait(s)
AgrEvo, Aventis CropScience	1999-2002 (2)	Altered flowering times allowing crossing of lines that normally flower at different times. This provides access to new hybrid varieties.
AgrEvo	1999 (1)	Altered nutritional qualities involving removing anti-nutritional qualities from canola meal so it is more suitable for animal feed
Seedex	1996-97 (1)	Altered oil profile, involving incorporation of gene from California Bay laurel to produce a cultivar from which laurate oil can be obtained
AgrEvo	1999 (1)	Increased yield through the introduction of dwarf characteristics
Hoechst Schering AgrEvo, AgrEvo, Aventis Crop Science	1998–2002 (5)	Fungal resistance, including blackleg and sclerotinia
Hoechst Schering AgrEvo, Seedex	1996–2000 (3)	Herbicide tolerance either to glufosinate ammonium or glyphosate
Pacific Seeds, Seedex	1992–97 (2)	Herbicide tolerance and male sterility (ensuring canola plants cross pollinate rather than self pollinate)
Aventis Crop Science	2000–02 (1)	Reduced pod shattering, leading to higher yields

Source: Genetic Manipulation Advisory Committee (2001).

GM canola in Australia

At the field trial stage in Australia for GM crops, canola is the second most trialed crop, behind only cotton. A wide range of traits are being investigated, including herbicide tolerance, fungal resistance, oil and nutritional quality, and yield and pollination characteristics (table 9). The canola variety closest to commercialisation is herbicide tolerant canola, which is expected to be submitted for approval for general release in 2003.

Implications of GM canola adoption: two scenarios

Background

Canada is the only producer of GM canola, apart from small quantities produced in the United States. Canada has a share of around 41 per cent of world trade (including intra-EU trade). Australia accounts for around a further 13 cent of world trade, while the European Union provides 38 per cent (table B6 in appendix B).

The main export destinations for unprocessed Canadian canola are Japan, Mexico, United States and China. (see appendix A for more details). The bulk of Canadian canola oil and meal go to the United States; smaller markets are Japan, the Republic of Korea, Hong Kong and China. The destinations for Australia exports of canola are the same as those for Canadian canola, except Australia has the ability to export canola to the European Union (table B9).

In Australia, canola that has been genetically modified to be herbicide tolerant has been extensively trialed. Two developers —Aventis Crop Science and Monsanto Australia —appear likely to apply to the Office of the Gene Technology Regulator soon for approval for commercial release. These developers are thought to be aiming at a release date in Australia of 2003.

Two main issues surround the commercial release. First, some have questioned the environmental safety of the variety, particularly pointing to the possibility that it will pass its tolerance of herbicides on to its weedy relatives. Second, the possibility of premiums for non-GM canola means that nonadopters are concerned about the potential introduction of GM material, either through cross pollination or co-mingling in the storage and handling system.

Analysis of costs and benefits

The cost and benefits equation for the introduction of GM crops needs to account for the direct agronomic consequences, the environmental implications, any additional marketing costs and losses of price premiums. The environmental risk assessments should be science based. McLean, Waterhouse, Evans and Gibbs (1997) detail the key scientific considerations with the environmental release of GM crops. Foster, Rees and Toyne (1999) note that economic factors should also be considered; the general economic principles for doing this are provided in Hinchy and Fisher (1991).

The direct agronomic benefits are straightforward: the yield improvement (or penalty), the price differences, the input savings (or additions) and the technology fee. Usually, the owner of the technology will be able to appropriate a part of these benefits via a substantial technology fee charged through the seed price.

Economic assessment of the environmental impacts of GM crops is beyond the scope of this paper. Rather, the focus is on the agronomic and marketing costs and benefits.

Scenarios

Two scenarios were evaluated using the AGLINK model of world agricultural trade to assess the market implications of wide scale adoption of GM canola in Australia. In the first, the impact of the agronomic benefits alone were assessed; in the second, the impact of the agronomic benefits, combined with the additional costs of keeping GM and non-GM product separate in the handling and storage process, were examined.

With the first scenario, the assumptions are as follows.

- The agronomic benefits of the GM variety in the Australian context are (a) a yield advantage of 7 per cent over varieties already in use and (b) a decrease in weed control costs (including seed costs) equivalent to a 3 per cent reduction in total production costs. (These were based on an extensive review of the literature — for example, Farm Central (2000) and Serecon (2001).)
- The adoption rate is 50 per cent, roughly the same as the adoption rate of GM herbicide tolerant canola in Canada.

The additional assumptions for the second scenario are as follows.

- Australia segregates its canola crop into GM and non-GM crop at the export level — identity preservation of non-GM grain that adds 10 per cent to the cost of delivering all Australian canola to the export level. The magnitude of this cost is broadly consistent with estimates by Buckwell, Brookes and Bradley (1998) and the Economic Research Service (2000).
- Canola oil and meal are not subject to identity preservation requirements. (The meal is used as livestock feed and the oil does not contain DNA that would identify it as being genetically modified.) The effect is that more canola could be exported as processed product rather than as seed.

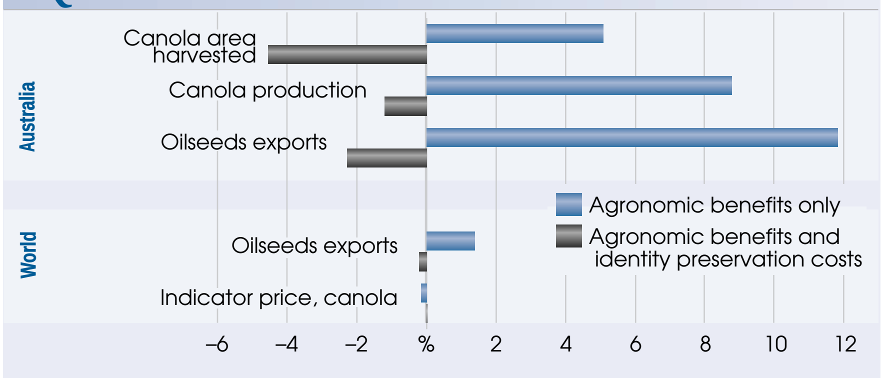
Discussion of results

The effects of each scenario on key market variables are illustrated in figure Q. Assuming only agronomic benefits — that is, yield improvements and reductions in the cost of production — the adoption of the GM variety would lead to Australian canola production increasing by 8.7 per cent by 2010, compared with the baseline, and Australia oilseed exports by 11.8 per cent.

At the world level, the impacts are small, with world oilseed exports increasing by 1.4 per cent and the additional supplies reducing the world indicator price for canola by 0.2 per cent. Australia would gain oilseed market share at the expense of the shares of Canada and the United States.

For Australia to produce the same level of canola production if it remained GM free, it is estimated that the premium for non-GM canola would have

Q Changes in key oilseeds market variables under two scenarios



to be around 10.4 per cent. At this stage, premiums of this magnitude do not seem to be available on a wide scale in world canola markets.

The imposition of identity preservation costs — the second scenario — were estimated to reverse these Australian gains in the world oilseed market. Australian canola production is estimated to fall by 1.2 per cent, compared with the baseline, and Australian oilseed exports are estimated to fall by 2.3 per cent. At the world level, the only impact is an estimated 0.2 per cent decline in world oilseed exports; the impact on world oilseed prices is negligible.

Given the assumptions, the model results suggest that wide scale introduction of herbicide tolerant canola may not be justified if consumer acceptance problems require elaborate identity preservation arrangements. Or, at least, a significant premium for non-GM over GM product could be necessary to offset the additional costs. These conclusions, however, are sensitive to the assumptions. Higher yields for GM canola, greater input cost savings and lower identity preservation costs could change these findings.

Comparative advantage in producing GM canola could vary across regions; that is, adoption at a level somewhat less than assumed in this analysis (50 per cent) may still be viable. The weeds problems, for example, may be so large in some regions that the agronomic benefits of the new technology may outweigh the additional costs of operating a mixed system or of any premiums lost. It is possible that the Australian canola industry will become segmented into regions that have a mix of GM and conventional varieties and other regions where the growing of GM varieties is not allowed. There are provisions under the *Gene Technology Act 2000* for the government to declare zones free from particular types of GM organisms.

Australia may have an advantage over some other countries in undertaking identity preservation of GM crops, because Australia's grain handling, storage and transportation system (with eighteen different grain export ports and associated transportation systems) makes it potentially feasible to have regions dedicated to either production of conventional grains (thus avoiding identity preservation costs) or a mix of GM and conventional grain.

Once introduced, GM crops are very difficult and costly to remove from production systems if any unforeseen problems emerge. The Starlink case illustrates this difficulty, with the cost of recalling product and eliminating the GM matter from seed stocks being substantial.

Commercial release of GM crops may require changes to existing laws and regulations to ensure the costs and liabilities are borne by those who impose them and so facilitate efficient allocation of resources. It may be necessary for governments to regulate to ensure appropriate buffer zones are maintained with GM crops so cross pollination does not affect the quality of neighbors' crops.

It is beyond the scope of this paper but the 'real options' approach to investment decisions, as described in Dixit and Pindyck (1994), is suited to aspects of the analysis of GM crop commercialisation decisions. This approach enables the three key characteristics of the decision — uncertainty over future profit streams, irreversibility, and the ability to delay the investment decision — to be incorporated into the assessment framework. Irreversibility, according to Dixit and Pindyck, is the condition whereby the firm, if it invests now, cannot costlessly disinvest should such an eventuality materialise. In the case of GM crops, these costs could include 'clean up' costs, as well as sunk costs. There would be high payoffs to extending this research to evaluate these options.

7

Case study: herbicide tolerant wheat

The announcement in January 2001 that the life sciences company Monsanto wants to commercially release herbicide tolerant wheat as early as 2003 has caused a deal of controversy. The position of the Canadian Wheat Board is that GM wheat (and barley) varieties 'should not be available for production in western Canada until proven technologies and associated protocols and procedures are in place to efficiently and effectively segregate transgenic from non-transgenic varieties in order to satisfy customer requirements, including, where necessary, guarantees that shipments meet agreed-upon maximum levels of transgenic varieties' (Canadian Wheat Board 2001). A similar position is held by US Wheat Associates (2001a), which is the US wheat industry's organisation responsible for export market development. The aim is this chapter is to assess the implications for the world and Australian grain industries of such a release in the United States.

Background

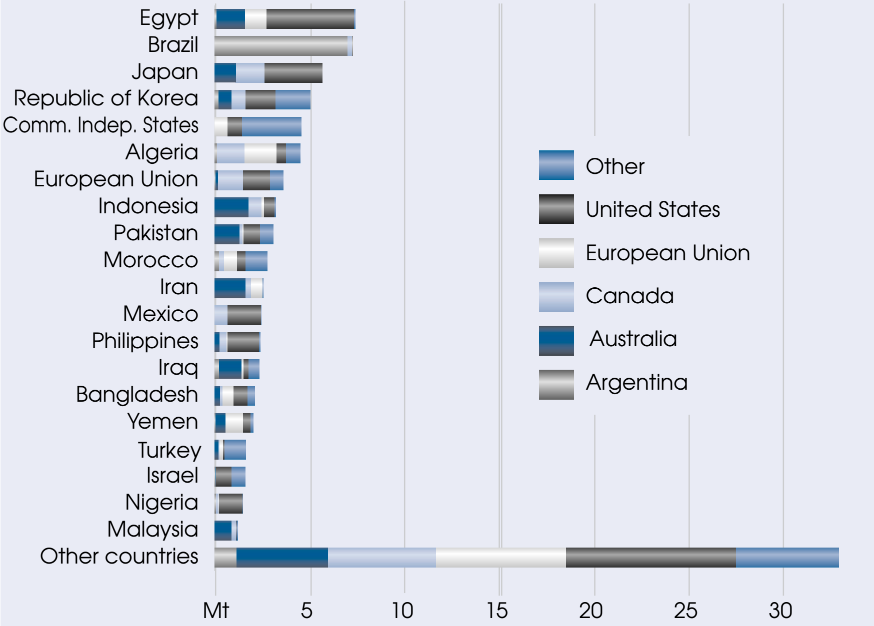
Rigorous evidence on the agronomic performance of GM herbicide tolerant wheat probably does not exist. Monsanto claims its GM wheat will boost yields by 10 per cent compared with existing varieties.

Conventional varieties of wheat that are tolerant of herbicides are also available. The available evidence suggests that these conventional herbicide tolerant varieties also offer agronomic benefits compared with comparable existing wheat types, but that they are inferior (in these terms) to the GM varieties. The conventional varieties, however, do not face the market access restrictions that the GM varieties are likely to encounter.

Despite the claimed agronomic benefits of GM herbicide tolerant wheat, there is a great deal of disquiet from wheat grower organisations and wheat marketers throughout the world about its commercial release. This is a result of the uncertainty about consumer acceptance and thus about the potential to lose market share to competitors.

The shares in 1998-99 of the major wheat exporting countries by the top twenty wheat importing countries are shown in figure R. The United States accounted for 30 per cent of world wheat exports, compared with Australia's

R **Trade in all wheat – origins and destinations, 1999 a**



a Includes wheat equivalent of flour and semolina exports.
Source: International Grains Council (2001).

near 16 per cent, the European Union's 14 per cent and Canada's 14 per cent. Its main customers were Egypt (16 per cent of total), Japan (10 per cent), Mexico (8 per cent), the Philippines (6 per cent), the Republic of Korea (5 per cent) and the European Union (5 per cent).

One estimate is that 85 per cent of the global customer base for US wheat currently opposes the development of GM wheat (Sayler 2001). In Japan, for example, the agency that is the sole government wheat buyer recently indicated that it would not buy GM wheat because consumer acceptance was an issue (US Wheat Associates 2001b). Moreover, Japan's wheat processing industry expressed scepticism about the reliability of any identity preservation system that could be put in place (US Wheat Associates 200lb).

Estimated market impacts of GM wheat: two scenarios

Two scenarios similar to those undertaken for canola were undertaken using the AGLINK model of world agricultural trade to assess the market implications of US adoption of GM wheat. In the first scenario, the impact of the agronomic benefits alone were assessed; in the second, the impact of the agronomic benefits, combined with the additional costs of keeping GM and non-GM product separate in the handling and storage process, were assessed.

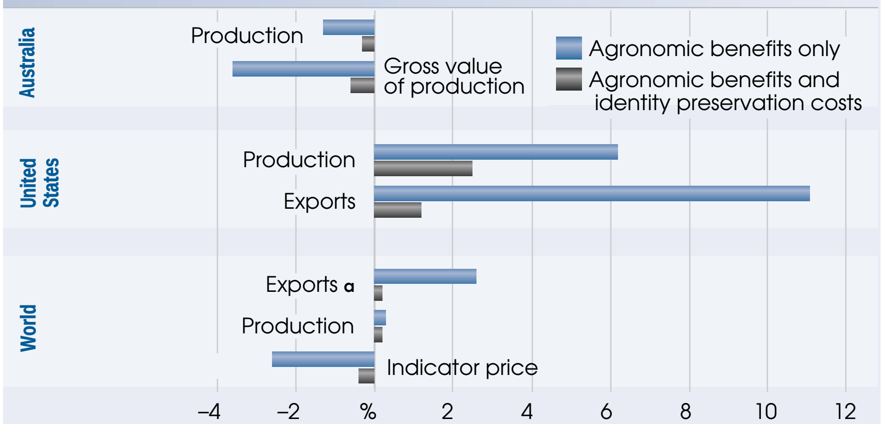
With the first scenario, the assumptions are as follows.

- The agronomic benefits of the GM wheat variety in the US context are a yield advantage of 10 per cent over varieties already in use and an increase in weed control costs (including seed costs) equivalent to a 1 per cent increase in total production costs.
- The US adoption rate is 60 per cent, around the level of adoption achieved with the other herbicide tolerant food crops, canola and soybeans.

The additional assumption for the second scenario is that the United States segregates its wheat crop into GM and non-GM product at the export position. This identity preservation of non-GM wheat is assumed to add 10 per cent to the cost of delivering all US wheat to the export position. The magnitude of this cost is broadly consistent with estimates in Buckwell, Brookes and Bradley (1998) and the Economic Research Service (2000).

The results of these scenarios are summarised in table 10 and illustrated in figure S.

S Changes in wheat market variables in 2010 under two scenarios



a Argentina, Australia, Canada, the European Union and the United States.

10 Estimated market impacts of US adoption of genetically modified wheat, 2010 a

	Grain			Livestock		
	Wheat	Coarse grains	Oilseeds	Beef	Pig meat	Poultry meat
	%	%	%	%	%	%
Agronomic benefits alone						
World						
Indicator price **a**	–2.6	–0.7	–0.7	–0.3	–0.5	–0.3
Production	0.3	–	–	–	–	0.2
Exports **b**	2.6	–0.4	0.1	–	–	–
Australia						
Producer prices	–2.3	–0.5	–0.4	–0.3	–0.4	–0.6
Production	–1.3	0.6	0.4	–0.2	0.4	0.1
Gross value of production	–3.6	–	0.1	–0.6	–	–0.5
Agronomic benefits but with identity preservation requirements						
World						
Indicator price	–0.4	–0.8	–0.4	–0.3	–0.6	–0.4
Production	0.2	–0.1	–	–	0.1	0.1
Exports **a**	0.2	1.1	0.2	–	–	–
Australia						
Producer prices	–0.4	–0.6	–0.2	–0.3	–0.5	–0.3
Production	–0.3	–	0.1	–0.3	0.1	0.1
Gross value of production	–0.6	–0.6	–0.1	–0.7	–0.4	–0.3

a Indicator prices are US export prices. **b** Argentina, Australia, Canada, European Union and the United States. – Negligible, less than 0.05.

Agronomic benefits alone

Under the first scenario — agronomic benefits alone — wheat prices are estimated to decline by 2.6 per cent by 2010, compared with the baseline, while US wheat exports increase by over 11.1 per cent. With the agronomic benefits being substantially passed on to consumers in the form of lower prices, world consumers of wheat products are estimated to be better off by about US$5.7 billion (in 2001 dollars) in 2010.

Reflecting that the Australian wheat industry would experience a significant loss in comparative advantage if they remained GM free, Australian wheat exports are estimated to decline by 2.6 per cent.

Agronomic benefits and identity preservation costs

With the second scenario — agronomic benefits and identity preservation costs — the benefits that flow from the agronomic advantages are almost negated. The world wheat indicator price would decrease by only 0.4 per cent by 2010, compared with the baseline. Comparative advantage in wheat production still shifts in favor of the United States, with its exports increasing (but only by 1.2 per cent.) World consumers of wheat products are also still better off. However, the estimated benefits accruing to them in 2010 are reduced by 74 per cent, to US$2.1 billion (in 2001 dollars). The loss in comparative advantage experienced by the Australian industry is substantially lessened under this scenario, with wheat exports declining by only 0.2 per cent.

In summary, the conclusion is very similar to that from the adoption of GM canola by Australia (see chapter 6) — that is, the US decision to adopt GM wheat becomes much less clear if elaborate identity preservation arrangements are necessary to meet customer requirements.

8

Case study: Biosafety Protocol

Nature of the Biosafety Protocol

The Biosafety Protocol could be an important determinant of market access for GM products. When finalised, the protocol will be an international agreement between the member countries of the United Nations Convention on Biodiversity that sets the rules for movements across national borders of living modified organisms that may affect the conservation and sustainable use of biodiversity. The protocol will deal with issues such as notification and responsibility for safety assessments before first-time trade occurs, and the importing country's rights of refusal. It establishes an international regime to ensure countries have sufficient information to make informed decisions on the environmental impact of the importation of living modified organisms (Hillman 2000).

After five years of talks, ministers and officials from 130 governments meeting in Montreal in January 2000 agreed on the draft text of what is intended to be a legally binding agreement — the Cartagena Protocol on Biosafety. This would enter into force for its members after fifty countries have ratified it, which Hillman (2000) estimates will take two years. The protocol is not supposed to affect the rights and obligations of governments under any existing international agreements (United Nations Environment Program 1999), although it remains problematic how a conflict would be resolved.

The protocol deals separately with living modified organisms intended for direct release into the environments (seed, fish, trees and animals) and those intended for food, feed and processing (so-called LMO commodities). The basis of the protocol is a prior notification and consent regime (advanced informed agreements), implemented via an internet based Biosafety Clearing House. An exporter must notify the importer of the first shipment of the living modified organism intended for direct introduction into the environment. The importing country would then make a decision about the import of the organism, based on a science based assessment of the risk to the environment.

For LMO commodities such as bulk grains, the exporter is not required to notify specific shipments; it will be sufficient for the exporting country to have notified the Biosafety Clearing House of its own approval for the domestic release of LMO commodities that may enter world trade. Shipments that may contain living modified organisms are required to be clearly labeled.

According to Hillman (2000), key issues for implementation have been left for further negotiation. These include: documentation requirements; standards for identification, handling, packaging and transport; liability and redress; and compliance. Another contentious issue with the protocol is how it relates to other international agreements, particularly the World Trade Organisation arrangements. Hillman (2000) took the preliminary view that any measure taken by a country under the protocol must be implemented in ways that are fully consistent with that country's obligations under these arrangements, but that this issue will require further detailed analysis.

Further, the operational provisions of the protocol are couched in terms of the precautionary principle, which holds that lack of scientific certainty due to insufficient scientific information and knowledge of the impact of the organisms shall not prevent a decision on the import of that organism. This provision of the protocol could be used to impose unjustifiable restrictions on trade and could weaken the scientific basis of risk assessment.

Economic effects of the protocol

Higher export transaction costs arise through the need for additional documentation of cargoes of products covered by the protocol (those potentially produced by genetic modification) and the costs of maintaining identity preservation to support this documentation. These costs are not confined to GM products. In particular, there could be additional documentation costs for those countries that have production mixes of conventional and GM organisms. The costs are likely to be much smaller for countries that do not have commercial releases of GM organisms because they avoid testing and identity preservation costs.

The actual cost level remains unknown because the documentation procedures under the protocol are yet to be defined. However, these documentation costs can be significant. As discussed earlier, testing to ensure that corn exports to Japan have not been contaminated with the non-approved GM corn variety Starlink is adding US$3–7 a tonne to the cost of shipping through sampling and testing alone. There may also be additional costs of identity preservation through the food supply chain.

Whether the protocol results in additional costs is debatable. Commercial trading activities are increasingly requiring similar documentation. The protocol, via the operation of the Biosafety Clearing House, could make this information more readily available. If the protocol increases costs beyond those commercially incurred, then the impact could be considered as a tax on *all* grain exports from countries that produce GM crops. Any additional costs would be largely passed on to consumers in the form of higher prices.

AGLINK was used to simulate the impact of an increase in grain export transaction costs. For every 1 per cent that the operation of the Biosafety Protocol raises grain export transaction costs from GM producing countries compared with what would happen under normal commercial disciplines, the cost to consumers of grain products is estimated to be around US$330 million a year by 2010.

The increased costs on shipments of *living* modified organisms could also provide incentives for increased processing of products before they are shipped. Instead of the export of oilseeds, for example, any additional costs under the protocol could perhaps be avoided via the export of oilseeds in the processed forms of oil and oilmeal. The cost also increases the incentive to feed grain to livestock rather than exporting it as grain.

Again assuming a 1 per cent increase in export transaction costs, trade in unprocessed grain declines from GM producing countries while trade in products that use grain inputs is increased. US exports of oilseeds, for example, decrease by an estimated 1.6 per cent by 2010, while US exports of vegetable oils and oilmeal rise by an estimated 4.8 per cent and 1.5 per cent respectively. It would benefit the US pig meat industry — with its exports up by an estimated 3.3 per cent by 2010 — because the industry would have access to cheaper grain than available to overseas competitors that rely on imports of US grain.

If the Australian grain industry and its export costs are unaffected by the Biosafety Protocol, then the industry would benefit slightly from such an increase in transaction costs in countries with GM crops. Under this scenario, increases in Australian production are estimated to be 0.4 per cent for oilseeds and 0.1 per cent for coarse grains by 2010. However, if the Australian grain industry adopts GM canola on a wide scale, then the estimated impact by 2010 of a 1 per cent increase in transaction costs from the Biosafety Protocol is a fall of 0.5 per cent in Australian oilseed production.

Effects on adoption rate of GM organisms

There appear to be divergent views on the impacts of the wording of the protocol in terms of the precautionary principle. The precautionary principle has the potential to slow the rate of commercialisation of GM crops through loading them with a much greater burden of proof of safety than with crops that are conventionally bred.

An alternative view is that the protocol will assist in the adoption of GM crops because adoption is facilitated by the building of risk assessment capabilities in some trading countries that previously may have been less able to afford to do so. The knowledge that appropriate risk assessment procedures have been undertaken with genetically modified crops may allay community concerns over adoption of these crops.

9

Conclusions

GM crops seem to offer present and future agronomic benefits. However, some consumer resistance to these crops and their products has meant that the future of GM crops is surrounded by uncertainty. Market premiums for non-GM grain are significant indicators of the market's acceptance of GM grain crops. If significant premiums for non-GM grains do not evolve on a wide scale, and given that GM grain crops offer agronomic benefits compared with conventional crops, eventual domination of the world grain market by GM grains would seem inevitable.

Much of the issue of market access for GM crops is driven by surveys of consumer attitudes that appear to show fairly widespread disquiet over GM products. However, these survey results may be at odds with how consumers will actually respond to GM crop products in the market place. Nevertheless, restrictions may prevent GM products from ever reaching the market or may load them with so many additional costs through compliance with regulations (such as traceability and labeling requirements) that they are uncompetitive with conventional products. Moreover, in a mixed production environment (GM and non-GM) the additional costs may extend to conventional products.

Given these uncertainties, the Australian grain industry is faced with the dilemma of whether to adopt GM crops. Certainly, the industry can learn from the experiences with GM crops of the United States and Canada. The obvious key lesson is that consumer acceptance levels cannot be ignored when deciding adoption rates for GM crops. The other key lesson is that any commercial release needs to be accompanied by institutional arrangements — particularly identity preservation arrangements — which can ensure that GM, conventional and organic industries can coexist in a way that maximises benefits to Australia. Again, given the uncertainties, flexibility to respond to changing circumstances must be an important consideration in the design of the arrangements.

Commercial releases of GM food crops in Australia are likely to be surrounded by controversy. It is important that regulatory processes in Australia are able to reassure developers of GM crops that there is a clear path to market if they satisfy all safety and marketing requirements; otherwise, private investment in the development of these novel crops is likely to diminish. This could affect the future competitiveness of the Australian cropping industry if consumer resistance to GM products abates.

The role of government is not necessarily to push gene technology as a winner in the Australian context. Rather, it is to develop the necessary legal, regulatory and enforcement structures to ensure the effective operation of the market. With appropriate arrangements, the allocation of resources between GM, conventional and certified organic grain markets can be left to market participants.

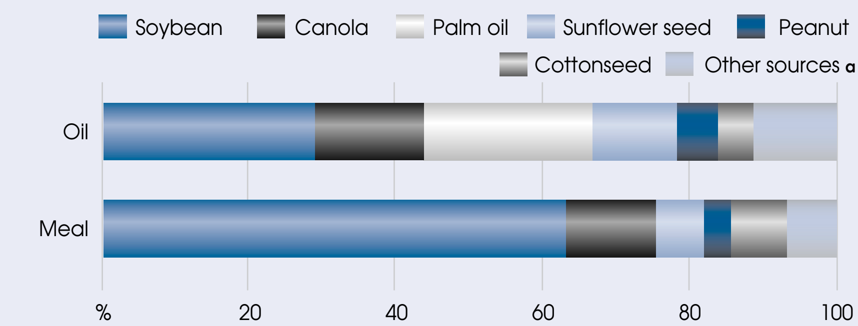
Appendix A

GM crops in the world grain market

The aim in this appendix is to describe in more detail the importance of the GM crops in world markets for grain. Production, consumption and trade information for each of these crops and their main products is provided in appendix B.

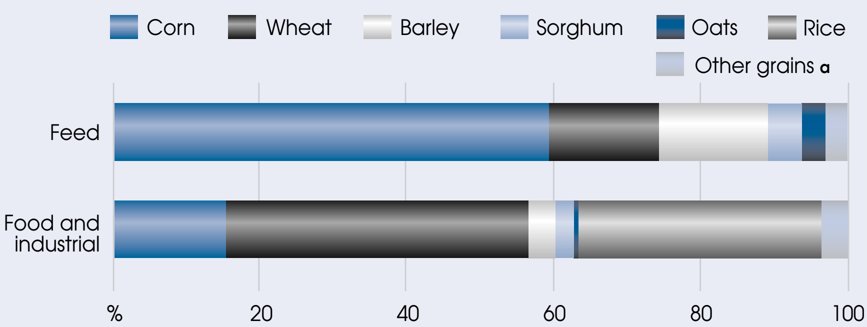
The types of crops that have been genetically modified are very important in world markets for vegetable oil and animal feeds. It can be seen from figure T that soybeans and canola provide around 45 per cent of the world's edible oils and 75 per cent of the vegetable protein meals that are usually

T Shares in world oil and meal consumption, by source type



a From fish, olives and palm kernels.

U Shares in world consumption of grain, by type



a Triticale, rye and millet.

fed to livestock. (With oilseed crops, meal is a byproduct of the crushing process that produces the oil.)

Corn, the only non-oilseed that has been genetically modified, accounts for nearly 60 per cent of world consumption of grain for livestock feed (figure U). It also makes up about 15 per cent of world consumption of grains for food and industrial uses.

Soybeans

Soybeans accounted for 53 per cent of world oilseed production in the five years to 1998-99, 63 per cent of world protein meal consumption, and 29 per cent of world vegetable and marine oil consumption (USDA 2001c). As shown in figure V, based on the American Soybean Association (2001), a wide range of food and other products is derived from soybeans. Nonfood uses of soybeans comprise less than 5 per cent of total production. It is widely believed that over 50 per cent of all processed foods contain ingredients derived from soybeans.

Virtually all GM soybeans are produced in the United States and Argentina. Together, these countries account for nearly 60 per cent of world soybean production and 70 per cent of the unprocessed soybean trade (table B5). These countries' soybeans are exported to a range of destinations (table A1). Brazil also approved herbicide tolerant soybeans for growing in 1999, but actual planting has been held up by a court challenge to this decision. Nevertheless, black market GM varieties may account for around 10 per cent of Brazil's total soybean production (Ewing 2000).

Corn

About 70 per cent of all maize is used as stock feed. It is consumed by humans in a very simply processed form or as processed products such as breakfast cereals, crispbreads and corn snacks. It is also refined into a wide range of different food and industrial products; in the United States, refining takes around 20 per cent of all corn. The primary food products from maize refining are:

- starches, used in a wide range of bakery products, confectionery, brewed beverages, pharmaceuticals and prepared food mixes;
- syrups, particularly high fructose corn syrup that is used as an artificial sweetener but also in a wide range of other food uses;

V Uses of soybeans and soybean products

Soybean oil products

Refined soybean oil

Edible uses
Coffee creamers
Cooking oils
Filled milks
Margarine
Mayonnaise
Pharmaceuticals
Salad dressings
Salad oils
Sandwich spreads
Shortenings

Technical uses
Anti-corrosion agents
Caulking compounds
Diesel fuel
Disinfectants
Dust control agents
Electrical insulation
Paints
Fungicides
Inks
Linoleum backing
Oiled fabrics
Pesticides

Glycerol, fatty acids, sterols

Soybean lecithin

Edible uses
Emulsifying agents
Bakery products
Confectionery
Pharmaceuticals
Nutritional uses
Dietary, medical

Technical uses
Anti-foaming agents
Alcohol
Yeast
Anti-spattering agents
Paints
Inks

Whole soybean products

Edible uses
Seed
Stock feed
Baked soybeans
Soy sprouts
Soymilk
Miso
Tofu
Soy sauce
Soy coffee
Full fat soy flour products
Bread
Confectionery
Doughnut mix
Frozen desserts
Instant milk drinks
Pancake mix
Pastry
Biscuits
Crackers

Soybean protein products

Soyflour concentrates and isolates

Industrial uses
Adhesives
Analytical re-agents
Antibiotics
Asphalt emulsions
Adhesives
Cosmetics
Fermentation aids
Films for packaging
Leather substitutes
Water based paints
Particle board
Plastics and polyesters
Pesticides, fungicides
Textiles

Edible uses
Alimentary pastes
Baby food
Bakery ingredients
Beer and ale
Confectionery
Cereals, grits
Dietary food products
Milk, food drinks
Hypoallergenic meat products
Noodles
Prepared mixes
Sausage casings

Soybean meal

Feed uses
Aquaculture
Bee food
Calf milk replacement
Cattle feed
Dairy feed
Pet food
Poultry feed
Pig feed

A1 Main export destinations for Argentinian and US soybean products [a]

Grain	Oil	Meal
Argentina		
European Union (63% of total)	China (15% of total)	European Union (57% of total)
China (7%)	Iran (12%)	China (8%)
China, Taiwan Province (7%)	Venezuela (9%)	Iran (5%)
Malaysia (5%)	Bangladesh (8%)	Egypt (5%)
Mexico (4%)	Pakistan (7%)	Malaysia (3%)
	India (4%)	Cuba (3%)
United States		
European Union (34% of total)	China (35% of total)	European Union (21% of total)
Japan (16%)	Hong Kong (9%)	Canada (11%)
Mexico (12%)	Mexico (7%)	Philippines (8%)
China, Taiwan Province (9%)	India (4%)	China (5%)
Korea, Republic of (6%)	Venezuela (5%)	Saudi Arabia (5%)
China (4%)		Australia (4%)
		Algeria (4%)

a For the period 1994–98.
Source: ISTA Mielke GmbH (1999).

- dextrose, used widely in fermentation and distillation processes, gelatin desserts, ice cream, confectionery, bakery products and prepared mixes (National Corn Growers Association 1999).

The co-products of corn refining are ‘solubles’ (used in antibiotics, chemicals, pharmaceuticals and yeast); gluten feed and gluten meal (used for livestock feed); and corn oil used mainly in margarine and as a cooking and salad oil (National Corn Growers Association 1999). Africa and China are the major consumers of food maize in unrefined form (table B3).

The United States provides 41 per cent of total world production of maize and over two-thirds of world maize trade (table B3) — a similar level of market domination to that which it has for soybeans. As well, the US accounts for around two-thirds of world trade in corn oil, one-quarter of corn germ meal trade and 96 per cent of the annual 6 million tonne trade in corn gluten feed.

The principal export destinations for the key US and Argentinian corn and corn products are shown in table A2.

A2 Main export destinations for Argentinian and US corn products [a]

Grain	Oil	Gluten feed	Gluten meal
Argentina			
European Union (23% of total)	Uruguay (35% of total)	European Union (99% of total)	European Union (100% of total)
Brazil (11%)	Russia (33%)		
Japan (10%)	Malaysia (6%)		
Other South America (17%)			
Egypt (6%)			
Malaysia (4%)			
United States			
Japan (32% of total)	European Union (22% of total)	European Union (98% of total)	Mexico (19% of total)
Korea, Rep. of (11%)	Saudi Arabia (17%)		Japan (18%)
China, Taiwan Province (11%)	Turkey (16%)		European Union (11%)
Mexico (8%)	Korea, Rep. of (6%)		China, Taiwan Province (9%)
Egypt (5%)	Mexico (5%)		Indonesia (8%)
European Union (4%)			Thailand (8%)

a For the period 1994–98,
Sources: ISTA Mielke GmbH (1999) for oil and gluten products, and data in USDA (1999) and International Grains Council (2001) for grain. A range of processed products from corn are omitted, such as starches, dextrins, high fructose syrups and processed foods such as breakfast cereals and corn chips.

Canola

In recent years canola overtook cottonseed as the second most important oilseed in terms of volume of production. It is used principally as a cooking oil and margarine. Its very low content of saturated fats has contributed to the strong growth in demand for canola over the past twenty years. The meal byproduct of canola processing is used as a stock feed.

Canada is the main grower of GM canola and also the principal exporter of unprocessed canola, with about half of the world's trade. The European Union, which produces only conventional canola and rapeseed, has traditionally been the other main canola exporter and is a large importer. Australia only recently emerged as an important canola exporter.

The principal export destinations for Canadian canola and canola products are shown in table A3. In the past five years, Japan took just over half of all

A3 Main export destinations for Canadian canola a

Grain	Oil	Meal
Japan (52% of total)	United States (75% of total)	United States (78% of total)
Mexico (15%)	Hong Kong (12%)	Japan (8%)
United States (9%)	China (5%)	Korea, Rep. of (4%)
China (8%)	India (2%)	Indonesia (2%)

a For the period 1994–98.
Source: ISTA Mielke GmbH (1999).

Canada's canola exports and the United States and Mexico accounted for a further 24 per cent. The European Union took around 25 per cent in the mid-1990s, but this market declined to almost nothing in recent years. In its place, China has emerged as significant market for Canadian canola.

Cottonseed

Cottonseed is a byproduct of processing cotton lint. It is crushed to produce oil and is used mainly in margarine and shortening and as a cooking and salad oil. The meal that results from the crushing process is used largely as a stock feed. The processing of cotton also produces hulls — which are used

A4 Main export destinations for Australian and US cottonseed products a

Grain seed	Oil	Meal
Australia		
Japan (76% of total)	Korea, Rep. of (53% of total)	Korea, Rep. of (95% of total)
Korea, Rep. of (12%)	Japan (26%)	Japan (5%)
United States (10%)	India (9%)	
	Thailand (6%)	
United States		
Mexico (74% of total)	El Salvador (22% of total)	Mexico (61% of total)
Japan (10%)	Canada (20%)	Korea, Rep. of (17%)
European Union (8%)	Japan (14%)	European Union (14%)
Canada (3%)	Korea, Rep. of (8%)	Poland (2%)
	European Union (5%)	
	Mexico (5%)	
	Nicaragua (5%)	
	Brazil (4%)	

a For the period 1994–98.
Source: ISTA Mielke GmbH (1999).

as a stock feed — and linters (fibres covering the seed) — which are used as a cellulose base in products such as paper, high fibre dietary products, casings for sausage and as a viscosity enhancer in toothpaste, ice cream and salad dressings (KPMG 1999).

The Central Asian Republics, large producers of cotton, account for over half of the world's cottonseed exports. The key importing countries for cottonseed oil are lower income ones such as Egypt, India and Russia. The European Union is also a prominent importer of both cottonseed and cottonseed meal (table B7)

It is estimated that, in 2000, 3.8 million hectares or 12 per cent of world cotton area was planted to GM varieties of cotton (table 2). The producing countries of GM cotton are mainly the United States, but also Argentina, Australia, China, Mexico and South Africa.

Most of cottonseed from GM cotton is consumed in the country in which it is produced; the only exporting countries with significant quantities of GM (nonfibre) product entering world trade are Australia and the United States. The main export destinations for these countries' cottonseed products are shown in table A4.

B Appendix

Statistics

B1 Genetically modified crops approved for commercial planting

Crop type	Company	Traits	Commercial planting approval
Tomato	Calgene	Delayed softening through suppression of polygalacturonase (PG) enzyme activity	Japan 1996; Mexico 1995; United States 1992
Canola	Calgene	Modified seed fatty acid content, specifically high laurate levels and myristic acid production	Canada 1996; United States 1994
Cotton	Calgene	Oxynil herbicide tolerance, including bromoxynil and ioxynil.	Japan 1997; United States 1994
Soybean	Monsanto	Glyphosate herbicide tolerance	Argentina 1996; Brazil 1998; Canada 1995; Japan 1996; Mexico 1998; United States 1994; Uruguay 1997
Squash	Upjohn (USA); Seminis Vegetable (Canada)	Resistance to viral infection, watermelon mosaic virus (WMV) 2, zucchini yellow mosaic virus (ZYMV)	United States 1994
Canola	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Canada 1995; Japan 1996
Canola	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Canada 1995; Japan 1997; United States 1995
Canola	Monsanto	Glyphosate herbicide tolerance	Canada 1995; Japan 1996; United States 1999
Canola	Pioneer Hi-Bred International	Imidazolinone herbicide tolerance, specifically imazethapyr	Canada 1995
Canola	Plant Genetic Systems Canada (PGS)	Pollination control system: male sterility; fertility restoration; phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Canada 1995; Japan 1996

Continued ➪

B1 Genetically modified crops approved for commercial planting

continued

Crop type	Company	Traits	Commercial planting approval
Canola	Plant Genetic Systems Canada (PGS)	Pollination control system: male sterility; fertility restoration; phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Canada 1995; Japan 1997
Carnation	Florigene	Increased shelf life (delayed ripening) due to reduced ethylene accumulation through introduction of truncated aminocyclopropane cyclase (ACC) synthase gene; Sulfonylurea herbicide tolerance, specifically triasulfuron and metsulfuron-methyl	Australia 1995; European Union 1998
Carnation	Florigene	Modified flower colour; Sulfonylurea herbicide tolerance, specifically triasulfuron and metsulfuron-methyl	Australia 1995
Corn	Monsanto	Resistance to European corn borer (*Ostrinia nubilalis*)	United States 1995
Corn	AgrEv	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Argentina 1998; Canada 1996; Japan 1997; United States 1995
Corn	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Argentina 1998; Canada 1996; Japan 1997; United States 1995
Corn	Dekalb Genetics Corporation	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Canada 1996; Japan 1999; United States 1995
Cotton	Monsanto	Glyphosate herbicide tolerance	Argentina 1999; Australia 2000; Japan 1997; United States 1995
Cotton	Monsanto	Resistance to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, tobacco budworm	Argentina 1998; Australia 1996; China 1997; Japan 1997; Mexico 1997; South Africa 1997; United States 1995

Continued ➪

B1 Genetically modified crops approved for commercial planting
continued

Crop type	Company	Traits	Commercial planting approval
Potato	Monsanto	Resistance to Colorado potato beetle (*Leptinotarsa decemlineata*, Say)	Canada 1995; United States 1995
Tomato	Zeneca Seeds	Delayed softening through suppression of polygalacturonase (PG) enzyme activity	United States 1995
Tomato	DNA Plant Technology Corporation	Increased shelf life (delayed ripening) due to reduced ethylene accumulation through introduction of truncated aminocyclopropane cyclase (ACC) synthase gene.	United States 1995
Tomato	Monsanto	Delayed ripening by introduction of a gene that results in degradation of a precursor of the plant hormone, ethylene	United States 1995
Canola	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium.	Canada 1996; Japan 1997; United States 1998
Canola	Monsanto	Glyphosate herbicide tolerance.	Canada 1996
Canola	Plant Genetic Systems Canada (PGS)	Pollination control system: male sterility; fertility restoration; phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Canada 1996; Japan 1998; United States 1999
Chicory	Bejo Zaden BV	Male sterility; phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	European Union 1996; United States 1997
Corn	Monsanto	Resistance to European corn borer (*O. nubilalis*)	Argentina 1998; Canada 1997; European Union 1998; Japan 1996; South Africa 1997; United States 1995; Argentina 1996
Corn	Novartis	Resistance to European corn borer (*O. nubilalis*); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Argentina 1996; Canada 1996; European Union 1997; Japan 1996

Continued ➪

B1 Genetically modified crops approved for commercial planting
continued

Crop type	Company	Traits	Commercial planting approval
Corn	Northrup King Co.	Resistance to European corn borer (*O. nubilalis*); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Canada 1996; Japan 1996; United States 1996
Corn	Pioneer Hi-Bred International	Resistance to European corn borer (*O. nubilalis*); glyphosate herbicide tolerance	Canada 1996; Japan 1997; United States 1996
Corn	Plant Genetic Systems Canada (PGS)	Male sterility; phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Canada 1996; United States 1996
Cotton	DuPont	Sulfonylurea herbicide tolerance, specifically triasulfuron and metsulfuron-methyl	United States 1996
Flax, linseed	Crop Development Centre, University of Saskatchewan	Sulfonylurea herbicide tolerance, specifically triasulfuron and metsulfuron-methyl	Canada 1996; United States 1999
Papaya	Cornell University	Resistance to viral infection, papaya ringspot virus (PRSV)	United States 1996
Potato	Monsanto	Resistance to Colorado potato beetle (*L. decemlineata*, Say)	Canada 1997; United States 1996
Soybean	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	United States 1996
Soybean	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Canada 1999;Japan 1999; United States 1996
Squash	Asgrow (USA); Seminis Vegetable (Canada)	Resistance to viral infection, cucumber mosaic virus (CMV), watermelon mosaic virus (WMV) 2, zucchini yellow mosaic virus (ZYMV)	United States 1996
Tomato	Agritope	Delayed ripening by introduction of a gene that results in degradation of a precursor of the plant hormone, ethylene	United States 1996
Canola	Plant Genetic Systems Canada (PGS)	Pollination control system: male sterility; fertility restoration; phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Japan 1997

Continued

B1 Genetically modified crops approved for commercial planting

continued

Crop type	Company	Traits	Commercial planting approval
Canola	Plant Genetic Systems Canada (PGS)	Pollination control system: male sterility; fertility restoration; phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Japan 1997
Canola	Rhône Poulenc Canada	Oxynil herbicide tolerance, including bromoxynil and ioxynil	Canada 1997; Japan 1998
Canola	Monsanto	Glyphosate herbicide tolerance	Canada 1997
Corn	Dekalb Genetics Corporation	Resistance to European corn borer (*O. nubilalis*); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	Argentina 1998; Canada 1997; Japan 1999; United States 1997
Corn	Monsanto.	Resistance to European corn borer (*O. nubilalis*); glyphosate herbicide tolerance	Canada 1997; Japan 1997; United States 1997
Corn	Monsanto	Glyphosate herbicide tolerance	Argentina 1998; Canada 1998; Japan 1998; United States 1997
Cotton	Calgene	Resistance to European corn borer (*O. nubilalis)*; oxynil herbicide tolerance, including bromoxynil	Japan 1998; United States 1997
Soybean	DuPont	Modified seed fatty acid content, specifically high oleic acid expression	Canada 2000; Japan 1999; United States 1997
Carnation	Florigene	Modified flower colour; Sulfonylurea herbicide tolerance, specifically triasulfuron and metsulfuron-methyl	European Union 1998
Corn	AgrEvo	Resistance to European corn borer (*O. nubilalis*); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	United States 1998
Corn	Pioneer Hi-Bred International	Male sterility; phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	United States 1998
Potato	Monsanto	Resistance to Colorado potato beetle (*L. decemlineata*, Say); resistance to potato leafroll luteovirus (PLRV)	Canada 1999; United States 1998

Continued ➩

B1 Genetically modified crops approved for commercial planting
continued

Crop type	Company	Traits	Commercial planting approval
Soybean	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	United States 1998
Soybean	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	United States 1998
Sugar beet	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	United States 1998
Sugar beet	Novartis Seeds; Monsanto	Glyphosate herbicide tolerance	United States 1998
Tomato	Monsanto	Resistance to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, tobacco budworm	United States 1998
Corn	Plant Genetic Systems Canada (PGS)	Male sterility; phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	United States 1999
Potato	Monsanto	Resistance to Colorado potato beetle (*L. decemlineata,* Say); resistance to potato virus Y (PVY)	Canada 1999; United States 1999
Potato	Monsanto	Resistance to Colorado potato beetle (*L. decemlineata,* Say); resistance to potato virus Y (PVY)	Canada 1999; United States 1999
Potato	Monsanto	Resistance to Colorado potato beetle (*L. decemlineata,* Say); resistance to potato leafroll luteovirus (PLRV)	Canada 1999; United States 2000
Rice	AgrEvo	Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium	United States 1999
Corn	Monsanto	Glyphosate herbicide tolerance	United States 2000

Source: Compiled from Agbios (2001).

B2 Field trials of genetically modified plants in Australia

Plant type	Trait sought	Number of trials	Organisation, trial period (no. of trials) a
Apple	Marker gene	1	Queensland Department of Primary Industries, 1994 to indefinite
Barley	Viral resistance	1	CSIRO, 1998–99
Barley	Marker gene	1	University of Adelaide, 1999
Barley	Altered quality	1	CSIRO, 1998–99
Canola	Herbicide tolerance	3	Hoechst Schering AgrEvo, 1996–2000 (2); Seedex, 1997–98
Canola	Herbicide tolerance and male sterility	2	Pacific Seeds, 1992–94; Seedex, 1996–97
Canola	Altered flowering	2	AgrEvo, 1999; Aventis Crop Science, 2000–02
Canola	Altered nutritional qualities	1	AgrEvo, 1999
Canola	Altered oil profile	1	Seedex, 1996-97
Canola	Fungal resistance	5	Hoechst Schering AgrEvo, 1997-2000; AgrEvo, 1998–99 (3); Aventis Crop Science, 2000–02
Canola	Reduced pod shatter	1	Aventis Crop Science, 2000–02
Canola	Dwarf characteristics	1	AgrEvo, 1999
Carnation	Altered flower colour	1	Florigene, 1994–95
Carnation	Altered vase life	2	Florigene, 1992–97) (2)
Carnation	Altered flower colour and altered vase life	1	Florigene, 1994–96
Carnation	Fungal resistance	1	Florigene, 1997–99
Chrysanthemum	Altered flower colour	1	Florigene, 1993–96
Clover (subterranean)	Herbicide tolerance	1	CSIRO, 1996–99
Clover white)	Viral resistance	2	Agriculture Victoria, 1996–2002; CSIRO, 1996-99
Clover (subterranean)	Altered quality	2	CSIRO, 1994–96; CSIRO, 1998–99

Continued ➪

B2 Field trials of genetically modified plants in Australia
continued

Plant type	Trait sought	Number of trials	Organisation, trial period (no. of trials) a
Cotton	Insect resistance	19	Deltapine Australia, 1993–2000 (9); CSIRO, 1992–2000 (7); Cottonseed Distributors, 1994–2000 (2); Agriculture Western Australia 1998–2000
Cotton	Herbicide tolerance	9	Deltapine Australia, 1994–99 (3); CSIRO, 1995–2000 (6)
Cotton	Insect resistance and herbicide tolerance	3	CSIRO, 1997-2000; Monsanto Australia, 1997–2000; Deltapine Australia, 1999–2000
Cotton	Fungal resistance	1	CSIRO, 1998–99
Cotton	Stress tolerance (waterlogging)	1	CSIRO, 1998–2000
Cotton	Promoters	1	CSIRO, 1998–2000
Field pea	Insect resistance	4	CSIRO, 1996–2000 (4)
Field pea	Altered quality	2	CSIRO, 1996–2000 (2)
Field pea	Fungal resistance	3	CSIRO, 1998–2000 (3)
Grape	Altered quality	1	CSIRO, 1998
Indian mustard	Herbicide tolerance	1	AgrEvo, 1998–2000
Lentils	Herbicide tolerance	2	Cooperative Research Centre for Legumes in Mediterranean Agriculture, 1999–2000 (2)
Lettuce	Viral tolerance	1	Queensland Department of Primary Industries, 1999–2000
Lupins	Herbicide tolerance	2	Cooperative Research Centre for Legumes in Mediterranean Agriculture, 1995–97 (2)
Lupins	Herbicide tolerance and viral resistance	2	Cooperative Research Centre for Legumes in Mediterranean Agriculture, 1997–98 (2)
Lupins	Altered quality	1	CSIRO, 1995–99
Papaya	Altered quality	1	Queensland Department of Primary Industries, 1999–2004
Papaya	Viral resistance	1	Queensland Department of Primary Industries, 1999
Pineapple	Altered ripening	1	University of Queensland, 1998-2004

Continued ➪

B2 Field trials of genetically modified plants in Australia
continued

Plant type	Trait sought	Number of trials	Organisation, trial period (no. of trials) a
Poppy	Marker gene	2	GlaxoWellcome, 1998–99; CSIRO, 1998–99
Poppy	Altered quality	1	GlaxoWellcome, 1999–2000
Potato	Viral resistance	4	CSIRO, 1991–99 (4)
Potato	Altered quality (reduced browning)	1	CSIRO, 1995–97
Potato	Agronomic properties	1	Florigene, 1992–93
Rose	Altered flower colour	2	Florigene, 1994–97 (2)
Sugar cane	Marker gene	1	University of Queensland, 1993–98
Sugar cane	Bacterial resistance	1	University of Queensland, 1996–2000
Sugar cane	Viral resistance	1	Bureau of Sugar Experiment Stations, 1997–2000
Sugar cane	Altered quality	2	CSIRO, 1997–2003 (2)
Tobacco	Insect resistance	1	CSIRO, 1998–99
Tomato	Altered ripening	3	Unifoods, 1992–94 (2); CSIRO, 2000
Tomato	Herbicide tolerance	1	AgrEvo, 1999–2000
Tomato	Insect resistance	1	Applied Horticultural Research, 1997
Wheat	Marker gene	2	CSIRO, 1996-97; University of Adelaide, 1998–99
Wheat	Altered quality	2	CSIRO, 1996–2001 (2)

a Aventis Crop Science was previously called Hoechst Schering AgrEvo and then AgrEvo. CSIRO is the Commonwealth Scientific and Industrial Research Organisation.
Source: Genetic Manipulation Advisory Committee (2001).

B3 Supply and distribution of corn and corn products

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Production	**592 172**	**575 201**	**605 312**	**606 154**	**583 055**	**592 379**	
Africa, other	36 254	38 008	38 451	37 095	40 025	37 967	6
Argentina	15 500	19 360	13 500	17 200	15 000	16 112	3
Brazil	35 700	30 100	32 393	31 641	38 500	33 667	6
Canada	7 380	7 180	8 952	9 096	6 800	7 882	1
China	127 470	104 309	132 954	128 086	105 000	119 564	20
EU 15	34 794	38 522	35 295	37 291	38 631	36 907	6
India	10 304	10 946	10 853	11 350	11 500	10 991	2
Mexico	18 922	16 934	17 788	19 000	18 000	18 129	3
South Africa	10 136	7 693	7 724	10 584	7 500	8 727	1
United States	234 518	233 864	247 882	239 549	253 208	241 804	41
Other	61 194	68 285	59 520	65 262	48 891	60 630	10
Exports b	**73 505**	**71 749**	**75 063**	**85 532**	**78 763**	**76 922**	
Argentina	10 828	12 222	7 882	11 700	10 000	10 526	14
China	3 892	6 173	3 340	9 935	6 000	5 868	8
EU 15	8 055	8 740	8 927	8 911	8 916	8 710	11
Hungary	1 122	1 236	1 829	1 786	200	1 235	2
South Africa	1 418	1 249	204	1 400	300	914	1
United States	45 655	38 214	50 310	49 209	50 802	46 838	61
Other	2 535	3 915	2 571	2 591	2 545	2 831	4
Imports b	**72 743**	**71 401**	**75 554**	**79 601**	**79 114**	**75 683**	
Africa	7 430	6 910	7 750	8 165	8 980	7 847	10
Chinese Taipei	5 742	4 474	4 575	5 023	5 100	4 983	7
Colombia	1 675	1 785	1 570	2 005	2 000	1 807	2
Egypt	3 201	3 245	3 687	4 600	4 600	3 867	5
EU 15	10 172	10 268	11 770	10 870	10 605	10 737	14
Japan	15 963	16 422	16 336	16 117	16 000	16 168	21
Korea, Rep. of	8 336	7 528	7 517	8 694	8 000	8 015	11
Malaysia	2 335	2 202	2 384	2 296	2 400	2 323	3
Mexico	3 141	4 376	5 615	4 911	6 000	4 809	6
Saudi Arabia	1 272	1 234	1 265	1 500	1 600	1 374	2
Other	13 476	12 957	13 085	15 420	13 829	13 753	18

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B3 Supply and distribution of corn and corn products *continued*

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Feed consumption	**387 773**	**401 257**	**402 467**	**419 201**	**422 016**	**406 543**	
Africa	14 180	14 686	14 870	15 902	16 227	15 173	4
Brazil	31 252	28 500	28 200	28 000	30 000	29 190	7
Canada	6 150	6 700	7 047	7 400	6 900	6 839	2
China	82 018	86 019	87 020	90 020	93 020	87 619	22
Egypt	7 000	7 250	7 250	7 850	8 000	7 470	2
EU 15	27 299	29 877	30 122	30 566	31 055	29 784	7
Former Yugoslavia	6 800	7 000	7 200	7 900	7 300	7 240	2
Japan	12 000	11 800	12 100	12 150	12 000	12 010	3
Mexico	7 093	7 150	7 512	8 050	9 200	7 801	2
United States	134 042	139 243	138 981	143 878	146 692	140 567	35
Other	59 939	63 032	62 165	67 485	61 622	62 849	15
Food consumption	**175 529**	**176 838**	**178 235**	**184 108**	**179 993**	**178 941**	
Africa	32 210	31 015	31 305	31 777	31 298	31 521	18
Brazil	5 191	4 955	5 415	5 191	5 400	5 230	3
China	27 400	27 400	27 300	26 900	27 000	27 200	15
EU 15	8 663	8 985	8 826	8 237	8 792	8 701	5
India	7 004	7 046	6 953	6 800	6 800	6 921	4
Japan	4 100	4 100	4 336	4 167	4 050	4 151	2
Mexico	14 997	14 852	15 525	15 361	15 200	15 187	8
United States	43 544	45 844	46 898	48 599	50 295	47 036	26
Other	32 420	32 641	31 677	37 076	31 158	32 994	18
Total consumption	**563 302**	**578 095**	**580 702**	**603 309**	**602 009**	**585 483**	
Africa	46 390	45 701	46 175	47 679	47 525	46 694	8
Brazil	36 443	33 455	33 615	33 191	35 400	34 421	6
China	109 418	113 419	114 320	116 920	120 020	114 819	20
EU 15	35 962	38 862	38 948	38 803	39 847	38 484	7
India	10 304	10 946	10 853	11 350	11 500	10 991	2
Japan	16 100	15 900	16 436	16 317	16 050	16 161	3
Mexico	22 090	22 002	23 037	23 411	24 400	22 988	4
United States	177 586	185 087	185 879	192 477	196 987	187 603	32
Other	109 009	112 723	111 439	123 161	110 280	113 322	19

a Average, 1996-97 to 2000-01. **b** Marketing year.
Source: US Department of Agriculture (2001c).

B4 Supply and distribution of wheat

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Production	**581 912**	**609 170**	**588 796**	**587 745**	**580 383**	**589 601**	
Australia	22 925	19 224	21 465	25 012	21 000	21 925	4
Canada	29 801	24 280	24 076	26 850	26 800	26 361	4
China	110 570	123 289	109 726	113 880	102 000	111 893	19
EU 15	98 506	94 181	103 085	96 885	104 946	99 521	17
India	62 097	69 350	66 350	70 780	75 754	68 866	12
Russian Federation	34 900	44 200	27 000	31 000	34 400	34 300	6
United States	61 980	67 534	69 327	62 569	60 512	64 384	11
Other	161 133	167 112	167 767	160 769	154 971	162 350	28
Exports b	**127 261**	**125 702**	**122 578**	**135 162**	**126 927**	**127 526**	
Argentina	10 198	10 666	8 400	11 600	12 000	10 573	8
Australia	19 225	15 343	16 473	17 844	16 000	16 977	13
Canada	19 501	20 134	14 705	19 165	19 000	18 501	15
EU 15	38 258	36 033	35 927	38 343	35 900	36 892	29
Kazakstan	2 320	3 560	2 295	6 514	4 000	3 738	3
United States	27 257	28 315	28 364	29 653	29 937	28 705	23
Other	10 502	11 651	16 414	12 043	10 090	12 140	10
Imports b	**120 102**	**125 265**	**121 523**	**131 040**	**125 915**	**124 769**	
Algeria	3 630	5 221	4 250	4 750	5 200	4 610	4
Brazil	5 800	6 100	7 300	7 555	7 900	6 931	6
Egypt	6 893	7 166	7 430	5 973	6 200	6 732	5
EU 15	22 904	25 781	25 174	25 091	24 775	24 745	20
Indonesia	4 201	3 664	3 117	3 739	3 700	3 684	3
Iran	5 567	5 211	2 056	7 021	7 500	5 471	4
Japan	6 264	6 200	5 959	5 960	5 900	6 057	5
Korea, Rep. of	3 465	3 917	4 689	3 811	4 000	3 976	3
Morocco	1 592	2 591	2 819	3 100	3 100	2 640	2
Russian Federation	2 631	3 120	2 490	5 000	2 000	3 048	2
Other	57 155	56 294	56 239	59 040	55 640	56 874	46

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B4 Supply and distribution of wheat *continued*

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Food consumption	**479 012**	**479 983**	**484 163**	**496 624**	**494 603**	**486 877**	
Australia	2 615	2 650	2 699	2 740	2 880	2 717	1
China	108 992	109 854	110 568	112 000	112 000	110 683	23
Egypt	12 365	12 755	12 874	13 113	12 890	12 799	3
EU 15	41 655	41 712	42 505	42 442	42 386	42 140	9
India	66 192	67 650	67 203	69 222	71 184	68 290	14
Iran	14 250	15 250	15 750	15 850	15 850	15 390	3
Pakistan	19 674	19 908	20 884	21 004	21 100	20 514	4
Russian Federation	23 774	23 412	23 688	24 182	24 200	23 851	5
Turkey	15 563	15 751	15 886	15 237	16 300	15 747	3
United States	27 026	27 394	26 951	27 660	28 140	27 434	6
Other	149 521	146 297	147 854	155 914	150 553	150 028	31
Feed consumption	**97 933**	**103 877**	**106 185**	**102 524**	**102 615**	**102 627**	
Australia	717	2 323	1 831	2 478	2 560	1 982	2
Canada	4 389	3 350	4 100	3 900	4 200	3 988	4
China	3 400	4 900	5 000	5 000	2 000	4 060	4
EU 15	38 462	41 481	46 305	45 952	51 150	44 670	44
Poland	4 000	4 200	4 500	4 500	4 200	4 280	4
Russian Federation	14 360	16 397	11 150	11 100	10 400	12 681	12
Ukraine	5 200	5 200	2 500	2 200	950	3 210	3
United States	8 371	6 818	10 734	7 724	8 165	8 362	8
Other	19 034	19 208	20 065	19 670	18 990	19 393	19

a Average, 1996-97 to 2000-01. **b** Marketing year.
Source: US Department of Agriculture (2001c).

B5 Supply and distribution of soybeans and soybean products

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	Mt	Mt	Mt	Mt	Mt	Mt	%
Soybean							
Production	**132 217**	**158 063**	**159 747**	**159 437**	**169 576**	**155 808**	
Argentina	11 200	19 500	20 000	21 200	25 000	19 380	12
Australia	84	93	109	110	105	100	0
Brazil	27 300	32 500	31 300	34 000	35 500	32 120	21
Canada	2 165	2 738	2 737	2 776	2 703	2 624	2
China	13 2 20	14 728	15 152	14 290	15 700	14 618	9
India	400	5 350	6 000	5 200	5 300	5 190	3
Paraguay	2 771	2 988	3 000	2 900	3 100	2 952	2
United States	64 780	73 176	74 598	72 224	75 378	72 031	46
Other	6 597	6 990	6 851	6 737	6 790	6 793	4
Exports b	**37 044**	**41 046**	**38 681**	**46 750**	**48 682**	**42 441**	
Argentina	750	3 231	3 200	4 100	5 500	3 356	8
Brazil	8 328	9 336	8 973	11 650	12 000	10 057	24
Canada	478	769	876	900	900	785	2
Paraguay	2 150	2 390	2 300	2 200	2 400	2 288	5
United States	24 110	23 760	21 898	26 492	26 535	24 559	58
Other	1 228	1 560	1 434	1 408	1 347	1 395	3
Imports b	**37 330**	**39 436**	**40 599**	**47 343**	**48 064**	**42 554**	
Argentina	650	1 250	500	450	300	630	1
Brazil	1 450	500	700	800	500	790	2
China	2 274	2 940	3 850	10 100	9 300	5 693	13
Chinese Taipei	2 632	2 387	2 150	2 300	2 350	2 364	6
EU 15	15 724	17 264	16 768	15 746	16 651	16 431	39
Indonesia	684	823	1 070	1 300	1 500	1 075	3
Japan	5 043	4 873	4 807	4 900	4 750	4 875	11
Korea, Rep. of	1 486	1 340	1 400	1 550	1 700	1 495	4
Mexico	2 720	3 479	3 764	3 950	4 250	3 633	9
Thailand	550	600	950	1 100	950	830	2
Other	4 117	3 980	4 640	5 147	5 813	4 739	11
Crush	**112 717**	**130 075**	**135 696**	**136 925**	**144 422**	**131 967**	

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B5 Supply and distribution of soybeans and soybean products *continued*

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	Mt	Mt	Mt	Mt	Mt	Mt	%
Soybean meal							
Production	**89 607**	**103 681**	**107 743**	**108 775**	**115 571**	**105 075**	
Exports b	**32 593**	**41 495**	**38 871**	**38 853**	**40 130**	**38 388**	
Argentina	8 050	13 131	13 219	13 400	14 750	12 510	33
Brazil	9 800	10 850	10 150	9 865	10 300	10 193	27
EU 15	4 751	5 224	5 040	5 134	5 065	5 043	13
India	2 450	2 600	2 800	2 350	2 250	2 490	6
United States	6 344	8 464	6 461	6 651	6 259	6 836	18
Other	1 198	1 226	1 201	1 453	1 506	1 317	3
Imports b	**34 389**	**37 602**	**39 476**	**39 435**	**39 693**	**38 119**	
Africa	1 419	1 608	1 735	2 073	2 107	1 788	5
Australia	325	375	400	400	415	383	1
China	3 600	4 198	1 400	633	175	2 001	5
EU 15	14 803	17 088	19 949	19 725	20 241	18 361	48
Indonesia	1 104	523	941	1 200	1 400	1 034	3
Japan	772	823	963	756	740	811	2
Korea, Rep. of	813	880	1 097	1 087	1 200	1 015	3
Middle East	2 022	2 205	2 331	2 379	2 355	2 258	6
Philippines	965	1 048	1 060	1 095	1 100	1 054	3
Thailand	983	800	875	1 100	1 170	986	3
Other	7 583	8 054	8 725	8 987	8 790	8 428	22
Consumption	**91 785**	**99 924**	**107 363**	**109 821**	**114 931**	**104 765**	
Africa	1 849	2 094	2 212	2 545	2 729	2 286	2
Australia	443	486	520	524	535	502	0
Brazil	5 400	6 535	6 900	7 225	7 350	6 682	6
China	9 539	10 897	11 416	12 504	14 345	11 740	11
Chinese Taipei	1 887	1 632	1 545	1 660	1 670	1 679	2
EU 15	22 334	24 740	27 655	26 677	28 014	25 884	25
Japan	3 585	3 674	3 650	3 650	3 650	3 642	3
Korea, Rep. of	1 900	1 824	1 984	2 092	2 140	1 988	2
Mexico	2 335	3 074	3 300	3 535	3 670	3 183	3
Middle East	2 752	2 908	3 206	3 472	3 538	3 175	3
United States	24 785	26 213	27 812	27 559	28 440	26 962	26
Other	14 976	15 847	17 163	18 378	18 850	17 043	16

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B5 Supply and distribution of soybeans and soybean products *continued*

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	Mt	Mt	Mt	Mt	Mt	Mt	%
Soybean oil							
Production	**20 318**	**23 562**	**24 735**	**24 904**	**26309**	**23 966**	
Exports b	**6 004**	**8 062**	**8 191**	**7 265**	**7760**	**7 456**	
Argentina	1 860	2 725	3 077	3 075	3400	2 827	38
Brazil	1 075	1 418	1 463	1 133	1340	1 286	17
EU 15	1 461	1 751	1 698	1 663	1626	1 640	22
United States	922	1 397	1 076	624	635	931	12
Other	686	771	877	770	759	773	10
Imports b	**5 904**	**6 814**	**7 981**	**6 987**	**7 334**	**7 004**	
Africa	618	692	855	1 009	1 018	838	12
Bangladesh	235	260	500	460	500	391	6
China	1 674	1 650	950	556	150	996	14
EU 15	602	624	635	548	549	592	8
India	49	236	833	790	1 150	612	9
Middle East	649	963	1 225	1 040	1 144	1 004	14
Pakistan	206	163	407	225	300	260	4
Other	1 871	2 226	2 576	2 359	2 523	2 311	33
Consumption	**20 544**	**22 308**	**24 525**	**24 449**	**25 909**	**23 547**	
Africa	720	797	958	1 111	1 150	947	4
Australia	62	63	65	48	57	59	0
Brazil	2 676	2 827	2 816	3 000	3 060	2 876	12
China	2 851	2 953	3 080	2 861	3 200	2 989	13
EU 15	1 871	1 799	1 834	1 628	1 805	1 787	8
India	706	1 095	1 805	1 582	1 974	1 432	6
Japan	665	667	675	684	684	675	3
Mexico	538	680	768	787	809	716	3
United States	6 471	6 922	7 101	7 283	7 416	7 039	30
Other	3 446	3 825	4 655	4 678	4 945	4 310	18

a Average, 1996-97 to 2000-01. **b** Marketing year.
Source: United States Department of Agriculture (2001c).

B6 Supply and distribution of canola and canola products

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Canola							
Production	**31 529**	**33 222**	**35 847**	**42 291**	**37 497**	**36 077**	
Australia	624	856	1 690	2 426	1 650	1 449	4
Canada	5 062	6 392	7 643	8 798	7 119	7 003	19
China	9 200	9 578	8 300	10 132	11 000	9 642	27
EU 15	7 330	8 636	9 508	11 319	9 223	9 203	26
India	6 942	4 935	4 900	5 110	4 200	5 217	14
Poland	449	595	1 099	1 132	950	845	2
Other	1 922	2 230	2 707	3 374	3 355	2 718	8
Exports b	**5 673**	**6 902**	**9 154**	**11 039**	**9 718**	**8 497**	
Australia	377	550	1 360	1 870	1 240	1 079	13
Canada	2 519	2 964	3 878	3 900	4 150	3 482	41
Czech Republic	56	50	170	400	330	201	2
EU 15	2 477	3 002	3 211	4 120	3 531	3 268	38
United States	79	126	246	136	185	154	2
Other	165	210	289	613	282	312	4
Imports b	**5 967**	**6 757**	**9 101**	**11 024**	**9 613**	**8 492**	
China	1	288	2 150	3 675	2 000	1 623	19
EU 15	2 504	2 968	3 066	3 139	3 475	3 030	36
Japan	1 996	2 091	2 174	2 200	2 100	2 112	25
Mexico	550	549	785	860	1 035	756	9
United States	259	355	310	242	175	268	3
Other	657	506	616	908	828	703	8
Crush	**28 851**	**31 192**	**32 021**	**37 274**	**35 688**	**33 005**	

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B6 Supply and distribution of canola and canola products *continued*

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Canola meal							
Production	**17 530**	**18 839**	**19 166**	**22 306**	**21 302**	**19 829**	
Exports b	**4 361**	**4 581**	**3 777**	**4 362**	**4 002**	**4 217**	
Canada	1 087	1 419	1 259	1 210	1 220	1 239	29
China	454	60	350	1 000	750	523	12
EU 15	1 443	1 662	1 547	1 574	1 469	1 539	36
India	950	1 000	160	130	125	473	11
Other	427	440	461	448	438	443	11
Imports b	**4 023**	**4 417**	**3 804**	**4 283**	**4 029**	**4 111**	
Chinese Taipei	90	90	60	81	80	80	2
EU 15	2 273	2 366	2 219	2 544	2 186	2 318	56
Japan	209	113	54	30	60	93	2
Korea, Rep. of	500	475	290	355	365	397	10
Other	85	129	98	141	138	118	3
United States	866	1 244	1 083	1 132	1 200	1 105	27
Consumption	**17 264**	**18 741**	**19 322**	**22 167**	**21 402**	**19 779**	
Australia	140	172	185	285	258	208	1
Canada	457	353	500	508	595	483	2
China	4 737	5 529	5 570	6 909	6 745	5 898	30
EU 15	4 914	5 447	5 758	6 356	5 926	5 680	29
India	2 675	2 400	2 440	2 720	2 375	2 522	13
Japan	1 285	1 282	1 280	1 250	1 240	1 267	6
United States	1 101	1 551	1 470	1 562	1 649	1 467	7
Other	1 955	2 007	2 119	2 577	2 614	2 254	11

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B6 Supply and distribution of canola and canola products *continued*

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Canola oil							
Production	**10 524**	**11 420**	**11 845**	**13 646**	**13 153**	**12 118**	
Exports b	**2 625**	**3 024**	**2 873**	**2 966**	**2 756**	**2 849**	
Australia	10	27	40	70	60	41	1
Canada	695	894	760	800	820	794	28
EU 15	1 602	1 735	1 782	1 869	1 642	1 726	61
United States	133	158	123	129	126	134	5
Other	185	210	168	98	108	154	5
Imports b	**2 547**	**2 691**	**2 639**	**2 743**	**2 690**	**2 662**	
China	281	400	175	40	80	195	7
EU 15	971	914	1 002	1 277	1 256	1 084	41
Hong Kong	154	154	150	100	100	132	5
India	30	66	241	160	200	139	5
Russia	110	196	120	130	100	131	5
United States	502	504	503	534	533	515	19
Other	499	457	448	502	421	465	17
Consumption	**10 506**	**11 037**	**11 563**	**13 242**	**13 141**	**11 898**	
Australia	88	94	90	126	124	104	1
Canada	487	485	543	540	579	527	4
China	2 969	3 274	3 325	4 285	4 145	3 600	30
Eastern Europe	552	559	575	665	653	601	5
EU 15	2 178	2 378	2 676	3 007	3 146	2 677	22
India	1 780	1 716	1 491	1 560	1 450	1 599	13
Japan	774	790	910	906	891	854	7
Mexico	283	282	408	426	458	371	3
United States	529	529	603	667	699	605	5
Other	866	930	942	1 060	996	959	8

a Average, 1996-97 to 2000-01. **b** Marketing year.
Source: United States Department of Agriculture (2001c).

B7 Supply and distribution of cottonseed and cottonseed products

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Cottonseed							
Production	**33 610**	**34 393**	**32 659**	**32 742**	**33 188**	**33 318**	
Africa	2 815	2 918	2 694	2 516	2 391	2 667	8
Australia	842	941	990	1 047	1 080	980	3
Brazil	490	650	782	1 066	1 250	848	3
China	7 560	8 280	8 100	6 900	7 840	7 736	23
EU 15	591	725	719	833	791	732	2
India	5 897	5 238	5 470	5 170	4 875	5 330	16
Pakistan	3 188	3 124	3 134	3 745	3 500	3 338	10
Turkey	1 175	1 190	1 260	1 150	1 175	1 190	4
United States	6 481	6 291	4 867	5 764	5 841	5 849	18
Uzbekistan	2 014	2 300	2 000	2 150	1 875	2 068	6
Other	2 557	2 736	2 643	2 401	2 570	2 581	8
Exports b	**817**	**982**	**916**	**1 056**	**1 095**	**973**	
Africa	230	254	259	245	248	247	25
Australia	225	300	305	363	405	320	33
EU 15	89	98	112	120	112	106	11
Syria	60	95	75	65	105	80	8
Turkmenistan	35	35	50	40	30	38	4
United States	105	135	62	180	181	133	14
Other	73	65	53	43	14	50	5
Imports b	**756**	**946**	**939**	**1 098**	**1 149**	**978**	
Africa	55	45	30	35	46	42	4
EU 15	238	253	226	235	230	236	24
Japan	180	200	179	175	174	182	19
Korea, Rep. of	22	49	35	35	30	34	3
Mexico	110	126	161	190	255	168	17
Turkey	100	140	85	88	90	101	10
United States	18	87	188	280	270	169	17
Other	33	46	35	60	54	46	5
Crush	**25 642**	**25 916**	**24 988**	**25 067**	**24 427**	**25 208**	

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B7 Supply and distribution of cottonseed and cottonseed products *continued*

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Cottonseed meal							
Production	**11 890**	**11 796**	**11 354**	**11 386**	**11 220**	**11 529**	
Exports b	**757**	**613**	**542**	**537**	**570**	**604**	
Africa	140	138	127	129	120	131	22
Argentina	205	189	156	100	121	154	26
Australia	36	19	32	15	12	23	4
China	190	100	72	145	125	126	21
United States	120	99	110	94	109	106	18
Other	66	68	45	54	83	63	10
Imports b	**676**	**528**	**531**	**497**	**523**	**551**	
EU 15	239	164	177	189	181	190	34
Korea, Rep. of	250	230	238	180	200	220	40
Mexico	90	70	77	92	105	87	16
Middle East	18	18	13	11	16	15	3
Other	79	46	26	25	21	39	7
Consumption	**11 844**	**11 670**	**11 408**	**11 348**	**11 175**	**11 489**	
Australia	191	226	192	145	146	180	2
Central Asian Republics	1 051	1 026	998	1 084	1 007	1 033	9
China	2 652	2 861	2 873	2 440	2 575	2 680	23
EU 15	462	393	393	432	422	420	4
India	2 185	1 865	1 965	1 845	1 760	1 924	17
Pakistan	1 247	1 220	1 225	1 480	1 335	1 301	11
Turkey	550	590	587	608	575	582	5
United States	1 494	1 450	1 065	1 175	1 052	1 247	11
Other	2 012	2 039	2 110	2 139	2 303	2 121	18

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B7 Supply and distribution of cottonseed and cottonseed products
continued

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Cottonseed oil							
Production	**3 702**	**3 705**	**3 569**	**3 557**	**3 544**	**36 15**	
Exports b	**234**	**248**	**163**	**177**	**175**	**199**	
Argentina	50	56	45	33	30	43	21
Brazil	13	10	10	29	40	20	10
Central Asian Republics	26	23	24	25	18	23	12
EU 15	27	25	18	16	14	20	10
United States	109	94	50	64	59	75	38
Other	9	40	16	10	14	18	9
Imports b	**290**	**230**	**185**	**224**	**199**	**226**	
Africa	32	17	10	14	21	19	8
Canada	28	38	37	38	40	36	16
Central Asian Republics	40	40	26	25	24	31	14
Egypt	25	11	6	9	15	13	6
EU 15	27	19	8	10	10	15	7
India	36	24	32	65	20	35	16
Japan	13	12	12	11	11	12	5
Korea, Rep. of	20	20	10	9	9	14	6
Other	69	49	44	43	49	51	23
Consumption	**3 786**	**3 696**	**3 610**	**3 621**	**3 554**	**3 653**	
Africa	360	343	322	314	292	326	9
Australia	77	67	77	55	54	66	2
Central Asian Republics	347	345	320	349	326	337	9
China	907	945	963	850	880	909	25
India	676	584	618	615	545	608	17
Middle East	280	277	292	313	315	295	8
Pakistan	271	272	276	325	300	289	8
United States	455	455	351	380	327	394	11
Other	413	408	391	420	515	429	12

a Average, 1996-97 to 2000-01. **b** Marketing year.
Source: US Department of Agriculture (2001c).

B8 Supply and distribution of rice a

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Production	**380 273**	**386 820**	**394 137**	**407 759**	**399 254**	**393 649**	
Africa	9 698	10 106	9 436	10 626	11 079	10 189	3
Bangladesh	18 882	18 862	19 854	23 066	24 000	20 933	5
Brazil	6 463	5 815	7 876	7 768	7 400	7 064	2
China	136 570	140 490	139 100	138 936	133 000	137 619	35
India	81 312	82 540	86 000	89 480	87 000	85 266	22
Indonesia	32 084	31 118	31 853	33 445	33 496	32 399	8
Japan	9 413	9 123	8 154	8 350	8 636	8 735	2
Myanmar	9 000	8 900	9 300	9 860	9 800	9 372	2
Philippines	7 265	6 488	6 674	7 772	8 095	7 259	2
Thailand	13 662	15 510	15 589	16 500	16 600	15 572	4
United States	5 453	5 750	5 798	6 502	6 025	5 906	2
Vietnam	18 003	19 094	20 108	20 747	21 100	19 810	5
Other	32 468	33 024	34 395	34 707	33 023	33 523	9
Exports c	**20 154**	**27 661**	**26 721**	**24 199**	**23 768**	**24 501**	
Australia	657	537	662	610	690	631	3
China	938	3 741	2 718	2 950	3 200	2 709	11
EU 15	1 408	1 388	1 339	1 377	1 399	1 382	6
India	2 100	4 000	3 350	1 400	1 150	2 400	10
Pakistan	1 834	2 099	1 837	2 104	1 800	1 935	8
Thailand	5 216	6 367	6 679	6 549	6 300	6 222	25
United States	2 488	2 755	2 730	2 804	2 553	2 666	11
Uruguay	645	576	745	685	685	667	3
Vietnam	3 327	3 776	4 555	3 370	3 800	3 766	15
Other	1 541	2 422	2 106	2 350	2 191	2 122	9

Continued ➪

B8 Supply and distribution of rice a *continued*

	1996 -97	1997 -98	1998- -99	1999 -2000	2000 -01	Average a	Share a
	kt	kt	kt	kt	kt	kt	%
Imports c	**17 815**	**25 228**	**26 199**	**21 283**	**22 278**	**22 561**	
Africa	3 509	4 344	4 687	5 106	5 283	4 586	20
Bangladesh	46	1 200	2 500	400	350	899	4
Brazil	849	1 400	900	600	490	848	4
China	663	573	504	595	615	590	3
EU 15	1 761	1 791	1 791	1 846	1 809	1 800	8
Indonesia	839	5 765	3 729	1 500	1 300	2 627	12
Iran	1 288	844	1 313	1 100	1 400	1 189	5
Iraq	744	630	779	1 261	1 300	943	4
Japan	500	499	554	619	750	584	3
Malaysia	563	638	630	617	658	621	3
Nigeria	350	731	900	950	1 200	826	4
Philippines	682	1 288	1 725	665	800	1 032	5
Saudi Arabia	814	660	775	750	950	790	4
Other	5 207	4 865	5 412	5 274	5 373	5 226	23
Consumption	**379 831**	**382 932**	**389 942**	**403 002**	**403 633**	**391 868**	
Africa	12 834	13 394	13 957	14 660	15 309	14 031	4
Bangladesh	19 139	20 062	21 900	23 632	23 900	21 727	6
Brazil	7 982	7 980	7 955	7 959	8 000	7 975	2
China	132 495	135 822	136 386	137 581	136 915	135 840	35
India	81 212	77 552	81 154	82 450	83 500	81 174	21
Indonesia	33 993	34 813	35 300	35 900	36 200	35 241	9
Japan	9 320	9 200	9 100	9 450	9 300	9 274	2
Myanmar	9 210	9 211	9 276	9 330	9 350	9 275	2
Philippines	8 027	7 800	8 000	8 400	8 550	8 155	2
Thailand	8 590	8 800	8 900	9 600	9 990	9 176	2
Vietnam	14 677	15 318	15 613	17 417	17 340	16 073	4
Other	42 352	42 980	42 401	46 623	45 279	43 927	11

a Milled equivalent terms. **b** Average, 1996-97 to 2000-01. **c** Marketing year.
Source: US Department of Agriculture (2001c).

B9 Australian canola exports, by destination

	1997-98		1998-99		1999-2000		2000-01 (to March)	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value
	kt	$m	kt	$m	kt	$m	kt	$m
Bangladesh	94.6	41.8	126.3	55.5	99.4	34.7	114.4	43.6
Belgium–Luxembourg	17.6	7.5	33.1	13.2			107.8	37.9
Canada	0.1	0.6	0.2	0.4	0.5	2.8	0.0	0.1
Chile			0.0	0.0			0.0	0.0
China	132.7	57.2	393.8	163.9	1212.0	405.4	206.8	73.6
Fiji	0.0	0.0			0.0	0.0	0.0	0.0
Germany	69.3	29.2	160.5	69.0			159.7	57.3
India	0.0	0.0	9.7	4.3	5.3	1.8	1.3	0.5
Indonesia	0.1	0.0	0.2	0.1	0.1	0.0	0.0	0.0
Japan	230.3	101.3	293.2	126.2	370.0	123.3	257.0	92.7
Korea, Rep. of								
Lebanon	0.0	0.0						
Malaysia	0.2	0.1	3.8	1.8	18.7	6.4	12.4	4.5
Mauritius					0.0	0.0		
Mexico	21.0	8.9	123.9	49.2	97.2	33.8		
Nepal			10.5	4.9			0.3	0.1
Netherlands	3.2	1.2	92.8	39.3				
Netherlands Antilles			0.1	0.0				
New Zealand			0.0	0.0				
Pakistan	20.9	8.0	42.8	17.1	56.2	18.8	222.1	82.8
Portugal								
Singapore	0.0	0.0	0.0	0.0	33.0	10.8	0.0	0.0
South Africa	0.0	0.0	0.1	0.2	0.1	0.2	0.0	0.1
Sweden					0.1	0.1		
Taiwan	0.0	0.0	0.1	0.0			0.0	0.0
United Kingdom			28.5	12.2				
United States	0.0	0.0	0.1	0.3	0.1	0.4		
Hong Kong							56.1	18.8
Total	**590.1**	**256.0**	**1319.8**	**557.6**	**1892.6**	**638.5**	**1138.1**	**411.9**

Source: Australian Bureau of Statistics (2001).

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