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17 August 2007

The Hon. Ian Armstrong
Chair, GM Crop Moratorium Review Panel NSW
(By email: gmcrops.review@dpi.nsw.gov.au)

Dear Mr Armstrong

I refer to the announcement on 16 July 2007 by the NSW Minister for Primary Industries regarding the Independent Review of the *Gene Technology (GM Crop Moratorium) Act 2003* and the invitation for submissions.

CSIRO is pleased to provide our perspectives in the attached document entitled "CSIRO's perspectives on the State and Territory GM crop moratoria".

Please do not hesitate to contact CSIRO's Biotechnology Coordinator, Dr Mikael Hirsch, by email at Mikael.hirsch@csiro.au or by telephone on (02) 6276 6961 should you or the Committee require any further information on our submission or on CSIRO's position in this regard.

Thank you for the opportunity to be a part of this process.

Yours sincerely

Dr Joanne Daly
Group Executive
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CSIRO's Perspectives on the State and Territory GM Crop Moratoria

August 2007

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Executive Summary

CSIRO acknowledges the public debate around the application of gene technology, particularly when it comes to genetically modified (GM) food crops. The issues regarding the use of GM organisms are complex and can be challenging for the Australian community.

CSIRO supports the responsible use of gene technology, including its use in food crops. We note the use of GM crops around the world is increasing rapidly. We have chosen to invest in biotechnology research, including gene technologies, because of their potential to:

- Provide Australians with improvements in health,
- Create a safer and more secure food supply,
- Generate prosperity, and
- Attain a more sustainable environment.

This submission gives examples of applications of GM technology under development by CSIRO that could benefit human health and environmental sustainability.

CSIRO supports a strong and effective regulatory approach to GM crops that is informed by the critical analysis of available scientific data and evidence. Such an approach has the potential to improve public confidence in the application of such technologies so that Australia can reap the benefits while managing the risks.

When reviewing their respective moratoria legislations, State Governments may wish to consider both the future global growth of GM crops and the potential impact of the moratoria on the innovative capacity of Australia, in particular on Australia's capacity to nurture research capability in the next generation of gene technologies.

Introduction

CSIRO supports a strong and effective regulatory approach to GM crops that is informed by the critical analysis of available scientific data and evidence. Such an approach has the potential to improve public confidence in the application of such technologies so that Australia can reap the benefits while managing the risks.

CSIRO is one of the largest and most diverse research agencies in the world. It is focused on addressing national and international challenges and opportunities, bringing to bear its powerful diversity of disciplines, experience and expertise in close partnership with the wider research community, governments, industry and the community.

CSIRO conducts agricultural research throughout Australia to improve the profitability and sustainability of Australian primary industries and the associated food and fibre-value chains that are built on these industries. CSIRO has a strong track record in improving the quality and yield of Australian grain, horticultural and fibre crops and innovation in the food industry. Increasingly, our agricultural work is assisting rural and regional Australia to continue their stewardship of the land in the face of global change.

CSIRO will always strive to use the best available technologies to achieve these outcomes to keep Australia at the leading edge of innovation. Genetic modification is one of these technologies.

Gene technology is not just a tool to develop GM crops, but is also a critical research technology which, together with functional genomics, gene silencing and other technologies, underpins all of our modern bioscience. CSIRO is by far the biggest research investor in this technology in Australia. In response to global trends CSIRO is seeking to rebuild its biological sciences to respond to major developments in transformational biology (genomics, computational biology and systems approaches).

Globally, the adoption of genetically modified (GM) crops has resulted in increased farm income, decreased pesticide use and associated environmental impact, and reductions in greenhouse gas emissions (Brookes and Barfoot, 2006). CSIRO has had extensive experience with the application and commercialisation of gene technology into the Australian cotton industry over the last ten years.

CSIRO acknowledges the public debate around the application of gene technology, particularly when it comes to GM food crops. The issues regarding the use of GM organisms are complex and can be challenging for the wider community. CSIRO supports the responsible use of GM technologies for the benefit of Australia. Our position on gene technology is given in Box 1. Examples of applications that CSIRO is developing using gene technologies are given in Attachment 1.

Purpose of this document

CSIRO welcomes the various reviews by the Australian State Governments of their moratoria on GM food crops, or herbicide tolerant canola in particular, which is the only GM food crop that is currently ready for marketing as a commodity. CSIRO recognises that the specific focus on the marketing of GM canola in these reviews since the overall consideration of public health and environmental safety were addressed as part of the national reviews of the regulatory framework in 2005/06.

CSIRO invests relatively little into GM canola research (~0.2 per cent of biotechnology research portfolio of about $200M). However, we wish to comment on the potential impacts of the moratoria on the national innovation system, including:

- The capacity for our industries to remain competitive through the adoption of new technologies;
- The restricted ability for Australia to capture the broader societal benefits from the next generation of applications of GM technologies; and
- The potential for a decline in skills in GM technologies (investment levels in research capabilities associated with GM food products has declined by 40 per cent in CSIRO).

This document provides a research-based perspective on issues relevant to the adoption of any future use of gene technology in Australian agriculture, including the global trends of adoption of GM crops. We provide some examples of near commercial-ready applications of CSIRO research to draw your attention to broader impacts the moratoria on commercial canola production can have on bringing these kinds of products to Australian consumers.

Box 1: CSIRO Position on Gene Technology

CSIRO believes there is a window of great opportunity for Australia, its community and industries, in the adoption of biotechnology research, particularly gene technologies. These give Australia scope to improve our health, create a safer and more secure food supply, generate prosperity and attain a more sustainable environment. Our position on this issue is:

- CSIRO will continue to play a valuable, ethical and responsible role in Australian and international efforts to develop beneficial new products and processes from gene technology.
- CSIRO will help to provide a clean, safe food supply, novel materials and products and a sustainable environment for all Australians through the use of appropriate biotechnology including gene technologies.
- CSIRO recognises and respects public interest and concerns on issues surrounding genetically modified organisms. We will continue to consult with the community, industry and government, listen to and recognise their concerns, and help inform Australians about gene technology. We recognise that values and opinions about these issues may change over time.
- CSIRO helps Australian industries to be world competitive in biotechnology and gene technology. We will commercialise our research in the most effective way in accord with our social responsibility, and promote the growth of local biotechnology companies. CSIRO will continue to conduct world-class research and train our scientists to the highest standards.
- CSIRO sees safety as a top priority in gene technology research. We set high internal biosafety standards and comply with relevant Government legislation and guidelines.
- CSIRO is committed to the ethical, lawful, transparent and accountable conduct of gene technology research.
- CSIRO supports the responsible protection of intellectual property rights in gene technologies as a means to stimulate further public research and innovation.
- CSIRO undertakes to investigate both the benefits and risks of gene technology research. We will help to enhance Australia's capability for environmental risk assessment.

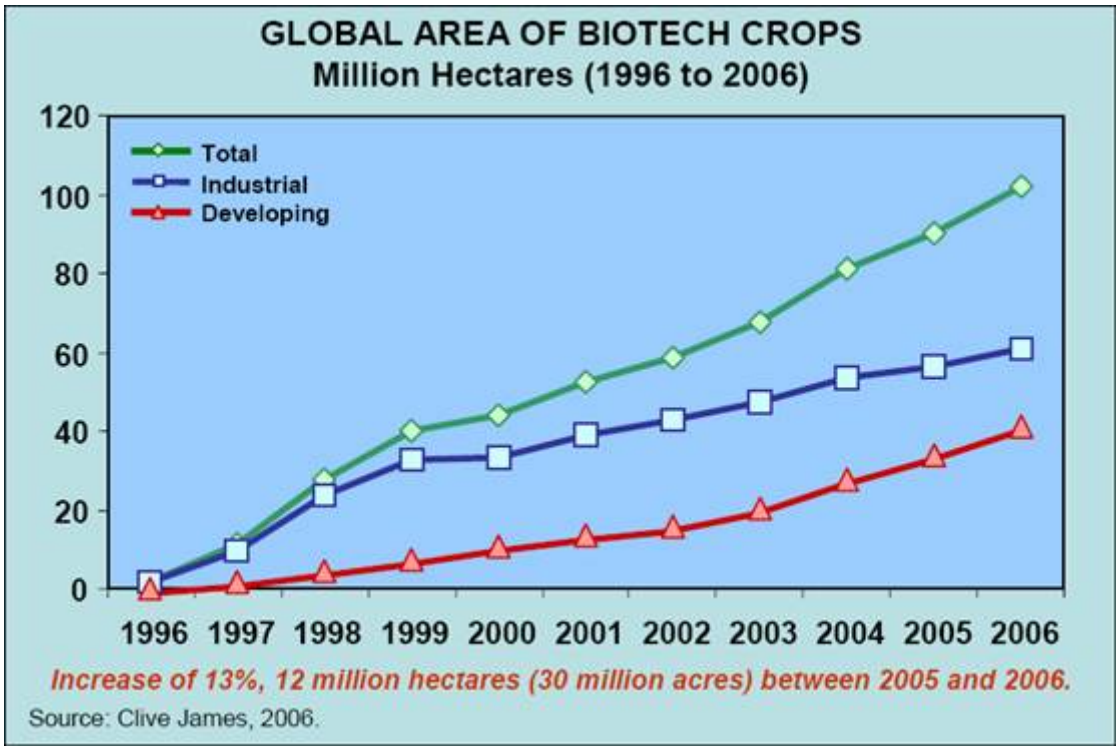
Issues Relevant to the Adoption of New Applications of Gene Technology in Agriculture

CSIRO notes that the global trends is for an increasing uptake of gene technology and that GM crops are expected to dominate some commodity markets, especially cotton, corn, soybean and canola.

The global trends of GM applications in crops

Since the introduction of GM crops (biotech crops) in 1996, the global uptake of the technology has been rapid (see Figure 1).

Figure 1: Uptake of GM crops since 1996 (from ISAAA Global Status of Commercialized Biotech/GM Crops: 2006 report)



The International Service for the Acquisition of Agri-biotech Applications (ISAAA) is a not-for-profit organisation that aims to deliver benefits of new agricultural biotechnologies to developing countries. According to the most recent report from ISAAA:

- During 2006 more than 10 million farmers in 22 countries planted 102 million hectares of biotech crops;
- More than 90 per cent of the farmers using this technology were in developing countries;
- The estimated global accumulated economic benefit of biotech crops for the preceding decade was US$27 billion (US$13 billion for developing countries and US$14 billion for industrial countries); and
- The estimated accumulated reduction in pesticides for the preceding decade was 224 300 MT of active ingredient.

The OECD is currently analysing future trends of GM crops as part of their BioEconomy 2030 project. A preliminary extrapolation of the above trends suggests that by 2015 the global production of soybean, corn, cotton and rapeseed/canola, which are the four main GM crops in current production,

could amount to 240 million hectares (draft report). These GM crops are having a large impact in a number of countries, some of which are Australia's competitors in international agricultural commodity markets. Science is globally-focussed — hence the development of gene technology and its application to crops is global.

General considerations for new GM crops

CSIRO has experience in introducing GM technology into Australian farming systems since we played a key role in introducing genetically modified Bt cotton into the Australian cotton industry. GM cotton varieties now represent more than 80 per cent of the entire Australian cotton crop. This successful introduction of a new technology was achieved because the whole supply chain was looking for a breakthrough technology to ensure its ongoing viability. The cotton industry faced a very uncertain future due to a heavy reliance on insecticides and the associated resistance to these insecticides in the primary pest species. Some of the main factors for success included the effective partnership between CSIRO, State agencies and the cotton industry and the vertically-integrated nature of the industry.

As Australia's experience with the introduction of GM crops is limited, a case-by-case approach is warranted, but based of its own experience CSIRO believes that it is important to consider three general issues before proceeding to commercialise any new GM crop:

1. Satisfactory regulatory controls over safety issues;

2. An industry-led approach to technology stewardship; and

3. Marketability and public acceptance of products from the particular crop.

CSIRO's perspectives on these issues are as follows.

1. Regulation and safety

In 1999 and 2000 the State, Territory and Australian Governments worked together to develop the Commonwealth *Gene Technology Act 2000*. The object of the Act is to protect the health and safety of people and to protect the environment by identifying risks posed by or as a result of gene technology and by managing those risks. The national Australian arrangements under the *Gene Technology Act 2000* set an international benchmark for managing the risks associated with GMOs.

While most GM products are regulated by agencies such as the Therapeutic Goods Administration (TGA), Food Standards Australia New Zealand (FSANZ) and the Australian Pesticides and Veterinary Medicines Authority (APVMA), GM products which were not already covered by an existing national regulation scheme are now regulated by the Gene Technology Regulator under a national system. The risk assessment methods employed by FSANZ and the APVMA are consistent with international standards set by the Food and Agriculture Organization and the World Health Organisation and their subsidiary bodies.

Australia has a very strong and comprehensive gene technology regulatory system. The nature and the level of regulation for GM products are described at BioRegs online: (http://www.bioregs.gov.au/questions/images/overview_matrix.pdf)

2. Stewardship

In Australia, product stewardship for GM crops has been in place since the introduction of GM Ingard cotton in 1996. CSIRO in partnership with other research providers, regulators and the industry were involved in the development of stewardship protocols that focused on delivering integrated pest management to the cotton industry while also maintaining the effective life of the new technology by ensuring that insects did not develop resistance to the new type of GM cotton.

Technology providers in the grains and canola industries also have stewardship programs which include aspects of the use of herbicides on conventional and herbicide tolerant crops. The APVMA has recognised the risk of the emergence of weeds that are resistant to herbicides and has required the sellers of herbicides to manage this risk. Herbicide resistance measures are incorporated within crop management plans (CMPs) that outline sound agronomic practices and integrated weed management programs designed to optimise the performance of the crop in question. All conventionally-bred herbicide tolerant crops have CMPs that incorporate herbicide resistance

management measures. Even broad-spectrum herbicides which are not yet used on HT food crops in Australia have herbicide resistance management plans. These plans have been developed by industry and researchers.

In May 2007, the American Biotechnology Industry Organization (BIO) launched a Stewardship policy for biotechnology-derived plant products. The BIO Stewardship policy focuses on minimising impacts on trade in commodity markets, which represents a further development of technology providers in taking responsibility for managing the impact of new technologies.

3. Public acceptance

Levels of public acceptance of GM products differ across the world. Although the gene technology industry has long held the opinion that GM food products giving benefits to the consumer will gain a higher level of public acceptance, CSIRO research indicates that this may not be the case when equivalent outcomes are offered by non-GM means (Cox *et al.,* 2004). However further CSIRO research found an overall likelihood to use GM oilseeds as fish food for farmed fish (as a source of omega-3, a health benefit) suggesting indirect consumption of GM foods may be acceptable (Cox *et al.,* in press, a). Further analysis of these data indicates that the Australian public are heterogeneous, importantly 41 per cent were found to perceive positive value in GM oilseeds containing omega-3 and only one in five were strongly “anti-GM” (Cox *et al.,* in press, b).

CSIRO research also confirms that people are more accepting of genetic modification of plant than of animal cells and more supportive of technological innovations that offer health or other pro-social benefits than of apparently non-essential innovations. This research has also found that the public’s in-principle acceptance of, or resistance to, genetic modification is more accurately explained in terms of general receptiveness towards science and technology than in terms of educational or informational deficiencies, issues of trust, or identification with environmental concerns or movements (Mohr *et al.,* 2007)

A recent survey by Biotechnology Australia has indicated a substantial increase in public acceptance of GM products between 2005 and 2007 (Eureka, 2007).

Examples of CSIRO GM research with potential to deliver benefits to the Australian community

Gene technology plays an important role in biological research. CSIRO has an extensive portfolio of bioscience research across a broad range of biotechnology applications. The focus of this research is on next generation technologies that have the potential to deliver substantial benefit to the Australian community.

Current CSIRO gene technology research offers the possibility of new products that could, if commercialised, have positive outcomes for the sustainability of Australian agriculture and health of Australians. Further details of these examples are given in Attachment 1. More examples of CSIRO's biotechnology research, including gene technology research, are available at http://www.csiro.au/files/files/p8uw.pdf.

Wheat with altered starch composition

CSIRO uses gene technology to discover the function of genes in a wide range of organisms, including plants.

Using GM technology we have recently developed a wheat variety where the activity of a set of wheat genes has been turned off giving starch with a very different composition to that usually present. This change means that the wheat flour has different properties which may be beneficial to a range of diet-related conditions that are prevalent in developed countries. Wheat with altered starch profiles, which is digested more slowly than standard wheat, could impact on the incidence of diseases such as colorectal cancer, diabetes and obesity. Gene technology has allowed researchers to produce wheat flour with altered starch to use in animal feeding trials and also to observe the finished product.

CSIRO, in collaboration with national and international partners, are now embarking on breeding to create wheat varieties with different ratios of starch types that will have significant positive health benefits when included in the diet.

The wheat work above gives an example where particular outcomes can be achieved both through a GM approach and a traditional breeding approach but where a combination of appropriate technologies can be used to speed up the delivery of certain solutions. In the above example GM technology has been used to knock out the function of a plant gene. However, there are situations where outcomes can only be achieved with a GM approach that adds a new gene. The examples below describe such projects where the outcome can only be achieved using genetic modification.

Insect resistant cotton

CSIRO research has already had a significant impact on the Australian cotton Industry. CSIRO, in partnership Monsanto, introduced insecticidal proteins from a common soil bacterium into our best conventionally-bred cotton varieties. The GM cotton is resistant to the major caterpillar cotton pests and now accounts for 80 per cent of the national crop. The wide scale use of GM insect resistant cotton has resulted in significant broader benefits associated with the reduction in pesticides.

Omega-3 oils

The health benefits of a diet rich in omega-3 long chain fatty acids have been well documented and include protection against coronary heart disease and certain important cancers. These fatty acids are also believed to be important in the maintenance of brain function. Usually the dietary source of long chain omega-3 oils is fish, which do not produce it themselves but acquire it through the food chain. Marine microalgae produce the long chain omega-3 fatty acids known colloquially as DHA and EPA and are the source of DHA and EPA in fish. CSIRO has recently announced a scientific breakthrough by demonstrating the production of DHA and EPA in land plants, including in canola. The production of high levels of DHA and EPA in oilseed crops such as canola could have several benefits including better nutrition and associated health outcomes because of cheaper, more plentiful sources of DHA and EPA. These terrestrial sources could also be valuable in relieving the pressure on marine fisheries which are under threat due to overexploitation.

Protection against bird flu

CSIRO has developed a technology that could be used to protect chickens against avian influenza (AI), including the H5N1 strain. In protected birds the virus would not be able to replicate and cause

disease thereby significantly reducing the chance of the spread of the virus to other birds, and to humans.

Reducing greenhouse gases

CSIRO research is aiming to make crop plants more efficient at using nitrogenous fertilisers. More efficient use of fertilisers will mean that less fertilizer will need to be applied and less unused fertilisers will be transformed into greenhouse gases.

Impacts of the Moratoria

CSIRO's Research Investments in Gene Technology

Since the introduction of the moratoria on the commercial production of GM canola in 2003, CSIRO has experienced a 40 per cent reduction in expenditure on projects specifically aimed at developing a GM food crop while expenditure on projects aiming to make non-food products has not significantly changed. Our interactions with the private sector indicate some hesitation to invest heavily in GM-based solutions until path-to-market is clearer than in the current climate.

CSIRO also has GM technologies developed for Australian agriculture that are currently awaiting commercial release. These technologies could be brought forward as commercial-release applications but there is little interest from industry to commercialise them in Australia at this time. These technologies have potential impact in the sphere of human and animal health as well as in agronomic performance and production inputs.

Decreasing research investment in the area of gene technology for Australian agriculture means that GM crops will not be available to the extent that they may have been in the absence of the moratoria. If the moratoria are removed, investment in the field is expected to increase, although there will be a lag period flowing from the need to rebuild our research capability.

This represents a science policy challenge to Australia. It is clear that as both bioscience and agriculture operates in an internationally competitive environment, there is an ongoing need to foster and retain both the research capabilities within the science systems as well as the capacity for agriculture to develop new products through new varieties of, or pest management practices for, agricultural crops that are specifically suited to Australian conditions.

External Factors that Influence CSIRO's Research Portfolio in GM

In 2005 CSIRO introduced a new 'whole of portfolio' investment process that connected its investment strategy to defined outcomes. CSIRO's future investments in gene technology will be influenced by a scan of the external factors such as community acceptance, the regulatory environment and a view on what technologies will enhance the profitability and sustainability (both financial and environmental) of the primary industry and food sectors.

CSIRO notes that a significant body of knowledge relevant to the production and marketing of canola has arisen in recent years, which provides a more detailed insight into how GM canola may impact on the marketing and trade of Australian agricultural produce within a global commodity system. CSIRO would like to draw the reviewers' attention to some of these reports that are listed in Attachment 2.

We note a range of these inputs are relevant for our investment considerations. These are as follows:

1. The competitive capacity of particular agricultural industries

In selecting applications of gene technology for future products, CSIRO takes into account how changing particular farming practices can bring significant improvements in the competitive capacity of the particular industry. For example our work in cotton breeding using GM technologies has enabled the industry to remain competitive while adopting more sustainable farming practices. However, it is important to keep a long term perspective on these issues.

In the case of GM canola, CSIRO notes that the Australian Oilseed Federation (AOF) states in its strategic plan, industry concern that Australia will be left behind and frozen out of markets in the next 5-10 years if biotechnology is a tool not available to it. The plan identifies the need for improved or new varieties for better weed control, in the longer-term improved performance with respect to drought and frost and also better nutritional characteristics. The plan sees the current heavy reliance on one technology (triazine tolerant canola) as a threat to the canola industry. The AOF plan is available at http://australianoilseeds.com/__data/assets/pdf_file/1517/AOFplan.pdf.

However, Canada is the world's largest producer and exporter of canola. The Canola Council of Canada has released (March 2007) a plan entitled *Canola growing great 2015*. The plan identifies innovation, including the use of GM technologies, as the best means of continually improving canola product quality, avoiding increased competition from other oilseed commodities and hedging against

political and regulatory uncertainty. The plan also foreshadows greater competition from increased Australian canola production should GM canola varieties be approved for commercial production. The *Canola growing great 2015* plan can be accessed at http://www.canola-council.org/PDF/Canolagrowing_great2015final.pdf.

2. Environment impact - Climate change and sustainability issues

CSIRO makes a substantial investment in research that addresses sustainability issues, including reducing the impact of climate change. The capacity to grow GM canola and other crops could stimulate further research to address these issues.
For instance, GM canola could, if grown in Australia, underpin the further adoption and improvement of conservation tillage practices by giving farmers more, and possibly easier, options for weed control using herbicides. Conservation tillage practices reduce soil erosion but also have two important greenhouse gas (GHG) mitigation advantages:

1. Conservation tillage uses far less fuel than full tillage farming systems. Brookes and Barfoot (2006) have calculated that the cumulative permanent reduction in tillage fuel use in Canadian canola since the introduction of GM HT canola in 1996 was 175.3 million litres which equates to a reduction in carbon dioxide emission of 482.03 million kg.

2. Conservation tillage increases soil carbon. Sequestering carbon in soil has been suggested as one potential measure for the mitigation of GHG emissions (Stern, 2006), however soils have a finite capacity to store carbon. The adoption of minimum tillage techniques will allow Australian agricultural soils to store more carbon than they otherwise would under full tillage practices.

In Australia there is a trend towards adopting biological farming techniques where soil carbon is increased to promote biological processes, improve soil heath/structure and, as a consequence, reduce the need for external inputs such as fuel, fertilisers and pesticides. It is possible that the combination of minimum tillage and biological farming systems, using GM crops with herbicide-tolerant and nitrogen-use-efficient (see Part 1 above) traits, could contribute to reducing net GHG emissions from Australian agriculture. However, much research is needed to ensure that reductions in GHG are maximised while maintaining profitability of the farming system(s).

Another environmental issue relates to potential benefit from changes in herbicide use patterns. Triazine herbicides, which are used on a significant proportion of Australia's canola crop, are considered by some to have undesirable characteristics such as high persistence in the environment leading to herbicidal or other activity in off-site aquatic ecosystems. In Australia, triazines have been found in groundwater, particularly under intensively cropped areas and sometimes at levels approaching the threshold for ecological effects (APVMA, 2004). There have also been safety concerns raised for some time in regard to triazines and an APVMA committee is currently reviewing the registration status of these herbicides.

In a 2003 report entitled *Conservation Farming Systems and Canola,* Dr Rob Norton of the University of Melbourne noted that, based on a scenario of GM canola replacing 50 per cent of the triazine tolerant (TT) canola and 40 per cent of the conventional canola, it could be estimated that 640 tonnes less triazine herbicide would be used each year. If TT canola were completely replaced by GM types, the reduction of 1280 tonnes of triazine would represent a 20 per cent reduction in the total annual use of triazine herbicides, which is estimated by Radcliffe (2002) to be in the order of 6000 tonnes.

In the Australian context it is likely that that the introduction of GM canola would see a reduction in the environmental impact associated with the use of herbicides on herbicide-tolerant canola. This is because the GM canola types are used with herbicides that are less persistent and toxic than triazines. However, it is unclear if a reduction in the total amount of herbicide will occur as triazines are used at low application rates.

3. Marketing and trade considerations

In setting research priorities, CSIRO also take into account the extent to which supply chains can deliver research outcomes that meet the expectation of end-use consumers.
We note that a recent report on supply chain capability has stated that the Australian grains industry has the capacity to deliver and manage the commercial introduction of GM canola, which is relevant for other grain products currently under development. CSIRO has provided technical advice to a companion document in which the grains industry has described the principles for process

management of grain in the Australian supply chain that would underpin the successful introduction of GM canola. The reports can be accessed at http://www.afaa.com.au/pdf/Delivering_Market_Choice_with_GM_canola.pdf and http://www.afaa.com.au/pdf/Principles_for_PM_Australian_supply_chain.pdf.

CSIRO has taken particular note of a number of recently released reports by the Australian Bureau of Agriculture and Resource Economics (ABARE). These reports relate to: Acceptance of GM canola in world commodity markets (ABARE, 2007a); the impacts of the release of GM canola on the Australian organics industry (ABARE, 2007b); and economic welfare considerations (ABARE 2005). In particular, ABARE concludes that:

- Continuing the current moratoria, and extending these to other transgenic broadacre crops, is expected to result in a loss of gross national product of $3 billion, in net present value terms, over the next ten years;

- The marketers of GM canola and of products based on livestock fed on GM materials, including GM canola, do not appear to be disadvantaged in the Australian and world markets — GM canola seems to be finding ready markets throughout the world at prices very similar to those received for conventional canola; and

- The commercialisation of GM canola would be expected to have very little, if any, direct impact on these organic sectors in Australia, but this conclusion does not extend to the potential impacts of commercialisation of other GM crops.

A key feature of the CSIRO science investment process is to have clarity of our ability to deliver research outcomes that deliver impact, preferably both in terms of economic growth and enhanced environmental sustainability, for Australian agriculture. Getting the right path-to-market signals is important feedback to guide our science direction. It is clear from the above discussion that the impact and issues surrounding the GM moratoria for canola are equally relevant and important for other gene technology applications that CSIRO may consider taking forward.

Conclusion

In reviewing their respective moratoria legislations, CSIRO suggests that the State Governments may wish to consider the potential impact of the moratoria on the innovative capacity of Australia, including the future trends of the global growth of genetically modified crops as well as the need to nurture the research capacity to enable Australia to reap the benefit of the next generation of gene technology applications.

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Attachment 1: Examples of CSIRO technology under development

The role of starch in the prevention of diet-related diseases

Diet-related diseases are a major socio-economic impost in Australia and other industrialised countries. They include coronary heart disease, colo-rectal cancer, diabetes and inflammatory bowel disease and they are appearing in developing countries with greater affluence. Dietary change can play a significant role in their prevention and management. For example, it is accepted that over 70 per cent of the more than 4 300 annual deaths from colo-rectal cancer in Australia do not have a genetic basis and are preventable. New consumer foods with improved nutritional attributes offer the opportunity to improve public health for this cancer and the other diseases of affluence. As part of this preventative strategy CSIRO are developing cereals with altered starch composition.

Most starch in food is broken down into glucose by the small intestine and absorbed into the body. However, resistant starch — or indigestible dietary starch — escapes digestion in the small intestine and passes into the colon. There it is broken down by the resident bacteria releasing short-chain fatty acids (SCFA) with the potential to promote bowel health and reduce the risk of developing colon diseases such as colorectal cancer.

In some foods, such as legumes, the content of resistant starch may be as high as ten per cent. However, in most modern processed foods, resistant starch levels are very low, which may contribute to large bowel dysfunction. Due to our diet of highly processed and refined foods, the average Australian consumes much less resistant starch than people in many other countries.
Diets high in resistant starch have been associated with improved bowel health and a reduction in the risk of colorectal cancer.

CSIRO has developed a new wheat variety using specific CSIRO-developed GM technology. The new wheat contains a high proportion of amylose, a slowly digested form of resistant starch that can be used to formulate foods high in resistant starch and with a low glycaemic index (GI), with suitable food qualities for use in breads, cereals and other foods.

Wheat high in resistant starch has the potential to improve the health across the entire Australian population. An initial animal feeding trial demonstrated that the new wheat may provide health benefits. Rats were fed a diet of either the high-amylose wheat or normal wheat. Indicators of bowel health, such as the presence of short-chain fatty acids, significantly improved in rats with a diet of the high-amylose wheat. The feeding trial showed no change in growth rates in the rats between those fed the high-amylose and those fed the normal wheats.

Omega-3 oils to improve nutrition

In a world first, CSIRO has developed plants that produce docosa-hexaenoic acid, or DHA, a healthy **omega-3 oil** component that is vital for human health and normally only available from fish sources. This breakthrough is an important first step towards improving human nutrition, reducing pressure on declining fish resources worldwide and providing Australian grain growers with new high-value crops. Research is continuing past this proof-of-concept stage to produce oilseed crops species that produce high quantities of DHA in their seeds.

Omega-3 oils are polyunsaturated fatty acids that are considered 'healthy oils'. DHA is a long-chain omega-3 fatty acid that is favoured for its health benefits. DHA is found in every cell membrane in the body and is vital for brain and eye development in infants. It is also now widely recognised for its ability to reduce the risk of coronary heart disease, type-2 diabetes, Alzheimer’s disease and asthma. Nutritional authorities recommend a daily intake of at least 500 milligrams of long-chain omega-3 including DHA, yet dietary surveys show that most Australians consume only a tenth of this amount. In test plants, CSIRO has shown that land-based plants can make their own DHA when they have the necessary genes. The CSIRO team has placed DHA-producing genes into a land plant. The resultant plant successfully produced DHA in its own seeds.

DHA and other long-chain omega-3 fatty acids are made by lower plant forms, including marine plants like microalgae. Fish do not create their own DHA; they acquire DHA when they eat microalgae. Fish accumulate high levels of DHA, which in turn can be consumed by humans as a source of DHA.

Higher level plants that grow on land do not have the same ability to produce DHA as the microalgae. Some land plants can make other types of omega-3, namely short-chain omega-3 fatty acids, but these are not as useful in the human diet as the long-chain fatty omega-3 fatty acids like DHA. Many foods are now enriched with omega-3 oils from fish, but with declining natural fish stocks, and aquaculture's current reliance on fish-based feeds, additional sources of long-chain omega-3 oils are urgently needed.

Although it will be some years before commercialisation, crop plants capable of producing useful levels of DHA in their own seeds would have many benefits.

DHA-enriched crop plants could provide consumers with cheaper and more varied sources of DHA – particularly valuable to those with fish allergies or who, because of cost, availability or choice, don't have a high level of fish consumption in their diet. Demand on natural fish stocks as a source of DHA would be reduced. Fish in aquaculture could be fed DHA-enriched plants, rather than continuing to use other fish as a feed, improving the sustainability of aquaculture without compromising quality.

Protection against bird flu

Ever since poultry became domesticated, there have been exchanges of avian influenza (AI) viruses between poultry species and humans. The most notable human influenza pandemic caused by a human-adapted avian virus was the ‘Spanish Flu’ of 1918.

In 2004 the highly pathogenic H5N1 strain of AI spread through bird populations in ten Asian countries resulting in the death or slaughter of over 100 million chickens. By January 2007 H5N1 outbreaks in poultry were reported in over 40 countries across three continents with over 200 million poultry slaughtered in Asia alone.

It is expected that AI viruses will continue to present a risk. As well as affecting the health and well-being of birds and humans, a major AI pandemic would cause significant economic, societal and community disruption.

There is currently no effective control over the continued spread of H5N1 influenza virus.
At present the virus can not easily spread from human to human but a major concern is that its widespread persistence in bird populations poses an increased risk to humans as every human infection provides the virus an opportunity to change form and become an infectious human-to-human influenza virus.

Research projects underway around the world include several different vaccination and medical treatments to limit or prevent the spread of an AI pandemic in humans, the outcomes of which will be critical to efforts to contain infection.

One of the most effective pandemic prevention strategies would be to reduce the incidence of AI among birds, particularly poultry.

The spread of AI remains uncontrolled in many countries especially where village poultry may come into contact with infected wild birds. In Australia strict quarantine, biosecurity and surveillance measures currently reduce the risk of an AI outbreak, however these measures alone cannot guarantee exclusion in the long term.

CSIRO is investigating whether a GM approach can be used to protect chickens from any strain of AI including H5N1. This could be achieved by inserting genetic information from the virus into a chicken so that its innate immune response is primed to deal with the virus should birds be exposed to it. The research will also investigate a range of possible applications of CSIRO’s gene silencing technology in the prevention of AI infection including therapeutic non-GM approaches. This is early stage research and it unlikely that products will be ready for commercial release in the near future.

Enhancing sustainability of cotton farming systems

Reducing pesticide use

Cotton is one of Australia’s most significant agricultural industries, exporting nearly 90 per cent of cotton fibre, for use in clothing and fabrics. Australia is the third largest exporter of cotton in the world. Bollgard® II, a CSIRO-developed genetically modified (GM) cotton now available for Australian cotton

growers, has reduced pesticide use by 80 per cent compared with conventional varieties, thereby improving the environmental sustainability and profitability of this billion dollar industry.

Bollgard® II was developed by inserting two genes from the soil bacterium *Bacillus thuringiensis* (Bt) into cotton. These genes produce two proteins toxic to the main insect pest of cotton – *Helicoverpa* – so that when the *Helicoverpa* caterpillars eat the Bollgard® II cotton they die. *Helicoverpa* have the capacity to render a cotton crop worthless if not managed. Previously pesticides were used to control these pests, but many of these also kill the beneficial insects. The advantage of using Bollgard® II with Bt genes is that only caterpillar species such as *Helicoverpa* are affected when feeding on the cotton plant. Bt has been used as the basis of safe natural insecticides for many years. CSIRO research has shown that there is a reduction of 64 per cent in the environmental impact of growing Bollgard® II cotton when compared to conventional cotton grown in the same year (Knox *et al.,* 2006).

Other benefits

A significant additional benefit from Bollgard® II cotton and preceding GM varieties has been the wider adoption of integrated pest management practices in the Australian cotton industry. Current GM varieties, including Bollgard® II, are also being used in large-scale trials with biological farming systems. These systems aim to increase soil biological activity by increasing soil organic matter, adding microbes or microbial stimulants and using plants to fix nitrogen rather than adding nitrogenous fertilisers. Although yields are the same with existing and biological farming systems, cost of inputs such as pesticides, synthetic fertilizers and fossil fuels could be dramatically reduced while soil health, soil structure and water-holding capacity could be significantly improved. Preliminary results are also revealing that Bollgard® II may be more water efficient than conventional varieties while maintaining its fibre quality. CSIRO is actively researching water use in cotton, but at this stage, there are no plans by CSIRO to address water use efficiency using gene technology.

Economic benefits have accrued to the Australian cotton industry as a result of the introduction of GM insect-resistant cotton. International comparisons have calculated a net financial benefit for Australian insect-resistant GM cotton growers of AUD$ 92 million in 2005 (Brookes and Barfoot, 2006).

Greenhouse gas abatement in agriculture.

The agriculture sector is the source of 14 per cent of greenhouse gas (GHG) emissions (Stern Review, 2006). Around 40 per cent of those emissions are from the nitrogenous fertilisers that are not taken up by plants. Most plants are unable to utilize more than one-half of the nitrogen fertiliser applied by growers; much of the remaining nitrogen fertiliser leaches into the air, soil and water and pollutes lakes, rivers, aquifers and oceans. A significant portion of the unabsorbed nitrogen fertiliser is transformed to gas, in the form of N_2O which is a potent GHG.

CSIRO and the Australian Centre for Plant Functional Genomics (ACPFG) have entered into collaboration with a US company to develop wheat and barley with significantly higher nitrogen-use efficiency (NUE). In field trials with GM canola overseas, it has been found that canola yield can be maintained while using ~65 per cent less nitrogen fertiliser. This means that yields could be maintained while the amount of nitrogen fertilizer, and GHG arising from its breakdown, are significantly reduced. GM NUE technology offers significant advantages in terms of climate change sustainability and also offers farmers large potential savings in the area of fertiliser inputs.

CSIRO and ACPFG will introduce the GM NUE trait into Australian cultivars and assess its performance under Australian conditions. If this technology is effective under Australian conditions, breeders, farmers and land managers will be involved in determining the best strategy to deploy it in new wheat and barley varieties.