

**Genetically Modified Crops, Science and the
Precautionary Principle**

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Chapter 6.

THE CASE OF GENETICALLY MODIFIED CARNATIONS

The GM carnation is of particular relevance to the GM issue in Australia because it has been locally developed and almost completely accepted. Commercially released in Australia 1995, the “blue” carnation may now be freely grown in home gardens and is cultivated and sold in the world’s major flower markets including Europe. The sober and matter-of-fact attitude that has been evident in the regulatory approach to the carnation provides a stark contrast with the emotional controversies that have arisen over GM canola and poppies.

The carnation (*Dianthus caryophyllus*) belongs to the Caryophyllaceae family, which includes both annual and perennial plants, and is made up of about 80 genera and 2000 species. The genus *Dianthus* consists of over 300 species that can be divided into two broad groups, carnations and pinks (OGTR, 2005b: 1; OGTR, 2006c: 1). Botanical records as well as current observations in the field suggest that the carnation’s natural distribution is confined to the Mediterranean, specifically Greece, Italy, Sicily and Sardinia (OGTR, 2005b: 2). It is understood to have been originally collected in the Pyrenees as flowers of a “magenta pink” colour (Galbally, 1960).

The word “carnation” is derived from the Latin *carnatio*, meaning “fleshiness” (*caro* = meat) and it was originally used to describe the flesh-pink colour of a pigment applied as a background wash by Elizabethan portrait painters (Flowers and Plants Association, 2007). The name *Dianthus*, meaning “divine flower”, is formed from the Greek words *dios* (Zeus or Jove) and *anthos* (flower). The species name, *caryophyllus* combines *karyon* (nut) and *phylon* (leaf) and means nut-leaved, a term that reflects the aroma of the carnation’s flower rather than the appearance of its leaves. The word *caryophyllus* was the original species-name for the Indian clove tree (now *Syzygium aromaticum*, previously called *Eugenia caryophyllus*) and its re-application to the carnation is a consequence of the clove-like scent the flower possesses (OGTR, 2006c: 1).

The original, natural form of the carnation is also known as the “wild carnation” or the “clove pink” and has been cultivated and bred for centuries. Due to its heterozygous nature, a large number of varieties and hybrids are available. In the Middle Ages, carnations, then known as “gillyflowers” or “gillofloures”, were particularly sought for their clove like perfume but their ornamental attributes both as garden specimens and as cut flowers have since become far more important (OGTR, 2005b: 1-2; OGTR, 2006c: 1-3). More recent selection for commercial purposes has been primarily concerned with visual or aesthetic characteristics, emphasising “flower size, petal number, stem length and disease resistance” (OGTR, 2005b: 2).

During the 19th century the carnation became commercially significant in France where it was propagated as a cut flower in glasshouses as well as in open fields. As interest developed across the Atlantic, French stock was taken to the USA, where the flower also became immensely popular (OGTR, 2005b: 2). By the early 20th century, carnations had become firmly established as a staple of the cut-flower industry throughout the western world.

The three most important types of carnation are “border” carnations, “annual” carnations and “perpetual-flowering” carnations. “Border” carnations are the oldest cultivated form of the flower and the closest to the original wild type, their current forms are the cumulative product of human selection of seedlings over hundreds of years (Galbally, 1960; OGTR, 2006c: 1).

“Annual” carnations are not strictly annual plants, but are biennial hybrids with a continual flowering characteristic that usually exhausts the plants after one season (OGTR, 2006c: 1). They are considered to be descended from crosses between the “border carnation” and the Indian pink (*Dianthus chinensis*) an east Asian plant that expresses this particular flowering characteristic (Galbally, 1960; OGTR, 2006c: 1, 2). “Perpetual flowering” carnations are the “thick stemmed, tall, heavy flowered, scentless” plants favoured by the cut-flower trade (OGTR, 2006c: 1). They originated in France in the 18th century as the “remontant” (literally “remounting”)

carnation, a large plant that was capable of blooming more than once a year and which also became known as the “tree” carnation.

Although the precise ancestry of the third type, the “perpetual flowering” carnation, is complex and somewhat uncertain, it is considered to have benefited greatly from the genetic influence of the US bred “William Sim” carnation. The “Sim” selection is of exceptional importance in the history of modern, commercial carnations and was bred in the 1930s by a Scot of that name who had emigrated to the US and established a carnation growing business in Saugus, Massachusetts. This type of carnation is normally cultivated in greenhouses (Galbally, 1960; OGTR, 2006c: 1, 2).

Carnations and Markets

Cited figures for the production and sales of both carnations and cut flowers in general are very variable, most probably because the floriculture industry tends to be highly fragmented, having many small and/or marginal operators at all levels. A good deal of trade passes either completely unrecorded or is recorded as an undifferentiated constituent of more general horticultural statistics such as fruit and vegetable sales, fresh and dried flower production, garden services or nursery products.

The values of international transactions in cut flowers, however, are usually recorded and this information is relatively easily accessed. Official trade data

is probably the most reliable indicator of the global fortunes of the floriculture industry, but estimates of total value of trade differ and will anyway clearly vary substantially from the value of total trade in cut flowers, which appears to be unknown. Australian cut flowers are considered to amount to only 1% of total trade (DPI NSW, 2005b).

International trade in cut flowers is a growing market and according to the OGTR was worth \$US 5.5B in 2004 (OGTR, 2006c: 3). The NSW Department of Primary Industry, in contrast, calculated the 2000 figure to be \$US 7B (NSW DPI, 2005b). Estimates of the much greater “total traded flower production” vary quite wildly, but are frequently quoted within the \$US20 – \$30 billion range. In terms of relatively recent, authoritative, Australian estimates, in 2006 the Research Manager of the biotechnology company, Florigene, Dr John Mason, reckoned the total value of the world’s cut flower market to be between \$US20 and \$40 billion annually (La Trobe University, 2006: 4). The extraordinarily wide margin for error is indicative of the scale of the difficulty involved in accurately assessing the size of the market.

Carnations have long been one of the handful of mainstays of the floriculture industry. Annual world production of carnations is estimated to be in excess of 10 billion blooms (AFAA, 2004a) but overall sales appear to have recently declined in terms of market share. In the 1990s, carnations, roses and

chrysanthemums were said to account for almost 50% of all cut-flowers grown and in 1995 carnations were estimated to comprise 15% of the entire cut-flower market (OGTR, 2005b: 2). Data from Holland, the centre of floricultural activity in Europe suggests that over the following decade the relative popularity of carnations slumped. By 2005 they were no longer listed among the top ten flower varieties sold (OGTR, 2006c: 3).

Nonetheless, this particular statistical example of a pronounced fall in relative popularity does not amount to evidence of broad disregard for carnations or of a condition of incipient decline. The reported tendency is not uniform, suggesting that such figures should be interpreted in the awareness of a certain frivolity that affects the floriculture market. Flower sales are subject to regional and local discrepancies, and abrupt and short-term troughs and peaks in response to “floral fashions and economic trends” (DPI&F, 2004).

Carnation production can be reliably considered to have a sound level of support in the flower market as its record demonstrates that their long-term market performance is very consistent. The UK Flowers and Plants Association, a promotional organisation for cut flowers and indoor plants, has great faith in carnations, describing them as “the UK’s best-selling cut flower, by miles” (Flowers and Plants Association, 2007). In Japan, carnations remain the second most popular flower sold, representing 8.2% of

sales, behind the Japanese cultural favourite, the chrysanthemum, which at 32 % accounts for nearly a third of all sales (OGTR, 2006c: 4).

Floriculture is an increasingly international business with a growing tendency for production to occur in developing nations. Among developed nations, the Netherlands (the world's largest exporter), Israel and Italy remain in the top six exporters (NSW DPI, 2005b). On average, the US, which has increasingly abandoned domestic cut-flower production in the face of cheap imports, imported just over 60% of its annual \$1B cut flower consumption between 1997 and 2001, mainly from Columbia, Ecuador and the Netherlands (Bonarriva, 2003: 18). In 2004, carnations (after roses and chrysanthemums) made up 9.4% of flower imports to the US, (OGTR, 2006c: 3-4). Over the 1997-2001 period, it imported on average \$100M worth of carnations annually (Bonarriva, 2003: 24).

Uses of Carnations

Carnations possess a strong clove aroma and have a related history of culinary use that stretches back to ancient times. The petals have been variously used as salad garnish and flavouring for wine, fruit, preserves, syrups and many other foods. They can be crystallised and have also been used in France to make the liqueur, green Chartreuse, for several hundred years (OGTR, 2006c: 4).

The petals of the carnation contain a very limited quantity of an essential oil that is used in the manufacture of high quality perfume and soap. Since the oil is extracted at the rate of only 100g per 500kg of flowers, or 0.02%, it is quite valuable. In its unadulterated form it is used only in products from the extreme quality end of the market, such as the perfumes of the great French fashion houses. Carnations and carnation oil have also traditionally been used in herbal medicine (OGTR, 2006c: 4).

Carnations in Australia

Commercial carnation crops have been grown in Australia since 1954. They are produced in significant quantities in Victoria, New South Wales, South Australia and Western Australia and in 2006 approximately 140 million cut-flowers were sold from a total cropping area of around 100 hectares (OGTR, 2006c: 4). Victoria is the largest carnation producer among the states and also leads in hydroponic production. Hydroponic systems have a number of advantages, the most important being that they overcome many of the problems of nutrition and disease control inherent to crop cultivation in a permanent solid medium such as soil. The most troublesome disease of carnations is fusarium wilt, which is a serious, soil-borne, fungal disease that is responsible for significant losses in traditionally produced crops (OGTR, 2006c: 4, 17).

Conventional Carnation Breeding

Successful carnation breeding is a difficult horticultural undertaking. Its particular complexities demand that those in the nursery industry practising it have a good grasp of theoretical and practical possibilities and limitations.

The OGTR describes the difficulties of seed production as “a chronic problem-for carnation breeders” (OGTR, 2006c: 11). In the first place, the plants are reproductively sensitive to both day length and temperature and when they do flower their pollen production does not coincide with stigma receptivity. The domesticated carnation, therefore, requires hand pollination with stored pollen in order to set seed (OGTR, 2006c: 10). Carnation pollen is produced in small quantities and is usually of very low viability (germination may be less than 10%), so seed set is typically either low or absent (OGTR, 2006c: 10, 11).

The development of new carnation varieties is hindered by some reproductively detrimental characteristics that have been unintentionally acquired along with aesthetically selected qualities and perpetuated through the continuous vegetative propagation methods necessary in carnation growing. The chronic pollen production problems already described are considered to be the result of repeated selection for flower quality combined with vegetative propagation over very time long periods (OGTR, 2006c: 11).

In its original, wild form *D. caryophyllus* is a simple, five-petalled flower, but its more familiar domestic descendant, with its densely whorled head, is hardly recognisable as the bloom of the same plant. It may have as many as 40 petals that completely enclose the reproductive organs and severely inhibit or even prevent normal pollination from occurring (OGTR, 2006c: 8, 11). Consequently plants selected for seed production in the quest for new varieties must be specially prepared in advance by cropping the flowers to expose the stigma (the female part of the flower that receives pollen). When the stigma becomes receptive, it is dipped in specially collected and stored pollen (OGTR, 2006c: 11).

Carnations do not breed true to type from seed because they are highly heterozygous plants with the complication of recessive genes. Nor is it possible to produce homogenous F1 carnation varieties, which require inbred parent lines, because carnations are susceptible to “inbreeding depression” in the third “selfed” generation (OGTR, 2006c: 5-7). Consequently carnations cannot be bred into proper “pedigreed” varieties and are inevitably either hybrids or “clones of selected individuals” (OGTR, 2006c: 5). “Annual” carnations are, nonetheless, usually propagated from seed, although other types are reproduced by vegetative propagation methods such as cuttings or layers (OGTR, 2006c: 5,7,8).

The Florigene Company and GM Carnations

Genetic modification of carnations has been successfully achieved in Australia in respect of the traits of improved vase life and altered colour. The “blue carnation” is one of only two GM crops that the states have allowed to be cultivated and over 4.5 million blue carnation blooms have been sold in Australia (OGTR, 2006c:5). It is also available and grown in the “key markets” of the USA, Japan and Europe (Florigene, 2007e). While the “blue” carnation now seems assured of becoming a major commercial success, the required commitment of resources, the long lead times, the ever-present possibility of failure and the vagaries of the flower market combine to make any investment in GM flower research a massive business risk.

The Melbourne-based biotechnology company, Florigene, which as a small “start-up company” called Calgene Pacific began research into flower colour manipulation in 1986, is now well established as one of the world’s technological leaders in this field (Ryan, 2003). The company’s original quest was to breed a blue rose, a classic ambition in flower breeding circles. In undertaking this challenge, Calgene Pacific was entering into a biotechnological race with a number of overseas plant-breeding concerns with their eye on the lucrative potential of copyrighted genes. In 1991 it gained a critical edge over its competitors when its researchers were first to isolate the genes responsible for blue flower colour from a petunia. Within

days of the company successfully patenting the genes a rival Japanese team announced that it had also made the same breakthrough (Ryan, 2003).

Dr Stephen Chandler, one of the Florigene scientists involved in the research wrote in a paper prepared for the Prime Minister's Science and Engineering Council in 1996 that carnation colour:

is due to two types of pigments, flavonoids and carotenoids. Carotenoids are found in many yellow or orange flowers, while flavonoids contribute to the red, pink and blue hues. The class of flavonoids most responsible for these colours are the anthocyanins, which are derivatives of a biochemical pathway that only operates in plants. The cyanidin and pelargonidin pigments are generally found in pink and red flowers, while delphinidin is commonly found in blue flowers. Delphinidin pigments have never been found in rose or carnation. The necessary gene for delphinidin production has been isolated by Florigene from petunia and transferred to carnation. (Chandler, 1996).

Biochemical production of the three groups of anthocyanins initially follows a common synthetic pathway before a critical point at which the activity of a specific enzyme determines whether the pigment will develop into cyanidin, pelargonidin or delphinidin. The genes responsible for the synthesis of the delphinidin precursor (dihydromyricitin, or DHM) are absent from the carnation genome, so conventional carnation flowers cannot synthesise blue pigment and it is not possible to produce blue flowers by conventional plant breeding means (Ag bios, 2001b; EGGT, 2001b: 7; OGTR, 2006c: 12-13).

The Florigene researchers inserted two genes from petunia (*Petunia hybrida*) that function together to synthesise delphinidin into the genome of a white

carnation, “White Unesco”. This particular carnation was selected to be the host because its evolved genome possesses a mutation in its anthocyanin synthesis encoding gene that prevents it from synthesising a functional form of the enzyme dihydroflavonol reductase (DFR) that is critical to the production of anthocyanin pigments (Agbios, 2001b; EGGT, 2001b: 7). The absence of any native pigment meant that after the insertion of the petunia genes, the blue hues of the introduced delphinidin genes could be expressed without encumbrance.

While this important success meant that the strength of Calgene Pacific was assured in the short term, ownership of the “blue gene” for flowers did not guarantee it an untroubled future. According to the company’s founder, Mike Dalling, the difficulties of retaining investor support over the long developmental years meant “relentless financial pressure” that repeatedly pushed it to the brink of insolvency (Ryan, 2003).

However, its immediate outlook was promising, especially when its scientific achievement delivered into its hands a very significant pecuniary windfall, in the form of its main competitor. In the financial aftermath of the discovery, Calgene Pacific acquired the assets of Florigene, a Dutch floriculture concern that had been ruined when its disappointed investors abandoned it after it failed to isolate the blue gene first. This acquisition enabled the Australian company to change its name to Florigene, which was a well established brand

name, and gain a foothold in “Europe’s lucrative cut-flower market” (Ryan 2003).

The “textbook” difficulties that Calgene Pacific/Florigene, subsequently faced were related to the costs, the long lead times and the chronic uncertainty that is associated with biotechnological research (Ryan 2003). Dalling has explained that rather than bringing the world to the company’s feet, the isolation of the blue gene placed even greater demands on his research program and team, and led to a long period during which the company merely “lurched on” (Ryan 2003).

It had taken five years to identify the gene responsible for the blue colour of flowers and it took a further four years to successfully transfer the gene to a carnation plant and produce the first “blue carnation bud” (Ryan 2003).

Another two years passed before the first “blue” carnation variety, “a mini-carnation called Moondust” could be offered on the market as a commercial variety (Ryan 2003). Thus, from an investment perspective, eleven years had elapsed before the research effort resulted in a product that could even begin to repay any of the original start-up costs.

Florigene has since released another five cultivars of “blue” carnation offering variation in shade, colour intensity and size (Moonshadow, Moonvista, Moonlite, Moonshade and Moonaqua) (Florigene, 2007). Four of

the “blue” carnations were placed on the GMO Register in March 2007, allowing them to be freely grown and sold in Australia without any requirement for a licence or supervision (OGTR, 2007c).

Although these flowers are commonly referred to as “blue”, they are probably more similar in colour to lilac or lavender than they are to bluebells or forget-me-nots. Indeed, Florigene takes care to avoid promotional misrepresentation of their product and “mauve”, “purple” and “violet” are the main words used in its literature to describe the colours of their carnations (Florigene, 2007; Florigene 2007b).

While “blue” carnations represent the commercially viable accomplishments of Florigene’s first twenty years of research into GM flowers, efforts to achieve its original research goal of breeding a blue rose have continued. In July 2004, Florigene announced the successful development of a prototype GM “blue” rose (Florigene, 2007b). Although, like the “blue” carnations, the roses that have been shown to the public are also more mauve than blue, the CSIRO-developed RNAi technology involved is new and enables plant breeders to exercise more precise control of certain genetic manipulatory outcomes (Physorg.com, 2005). RNAi (“RNA interference”) technology utilises the ability of double stranded RNA to “silence” gene expression and has has a number of identified and potential applications (CSIRO, 2007).

Unlike the “blue” carnations, the new rose is, in theory, genetically capable of expressing a range of purely blue colours, but several complications of the relatively simple process of colour formation through gene expression remain to be explored. A number of other genetic and environmental influences are either known or thought to be involved in the process of pigment production (Florigene, 2007d; Physorg.com, 2005; Tesselar, 2004).

Most important among these is petal pH - or more specifically the pH of vacuoles in epidermal petal cells. This factor can influence pigment chemistry in several ways and is the main focus of research. Pigments are located in the large vacuoles of the epidermal cells of petals and the quality of their colour (in this case, the “redness” or “blueness” of the blue) is pH sensitive (Florigene, 2007d; Physorg.com, 2005; Tesselar, 2004).

Since attempts to identify a suitable rose with higher petal pH have not been fruitful, one avenue of research now being investigated is the application of RNAi technology to the rose to control pH. This approach involves silencing genes to identify those influencing petal pH (Physorg.com, 2005).

Florigene’s promotional literature suggests that it is confident that its research will ultimately produce a “true blue rose” (Florigene, 2007b).

In 2006, the Japanese parent company, Suntory (as Florigene) successfully applied to the OGTR for a licence for the controlled release of nine torenia

hybrids modified for flower colour. *Torenia* belongs to the snapdragon family and these modified forms produce both solidly pigmented and variegated flowers involving white, blue, pink and yellow colours (OGTR, 2006d: 2). The introduced genes include partial gene sequences engineered to suppress unwanted colour expression and complete gene sequences that promote desired pigment synthesis. The partial sequences involved were extracted from *torenia* genetic material, while the complete sequences were sourced from snapdragons and geraniums. These plants were originally engineered in Japan (OGTR, 2006d: 2, 5).

Over most of its history, Florigene has continued to devote a significant research and development effort to solving the problem of short carnation vase life. Once a conventional carnation is cut, it dies quite quickly. A properly kept bloom will typically last for about a week, which means that a consumer could realistically expect a specimen from a retail source to remain attractive for only two or three days (OGTR [GMAC document], 1993: 1; Ryan, 2003). For this reason, chemical preservatives that can extend carnation vase life for an extra week or so have been routinely used in the flower industry for a long time. The chemicals that have conventionally been used for this purpose, such as silver nitrate and silver thiosulphate, contain “the heavy metal pollutant silver or other toxic compounds” (OGTR, 1993: 1). The UN’s Biosafety Information Network and Advisory Service (BINAS) concisely explains the use of preservatives:

After being harvested, carnation flowers have a defined “vase life”, or time for which the flowers will stay fresh prior to beginning to shrink, dry out and die. This senescence process is triggered by the production of a gaseous hormone (ethylene) by the flower. Flower death can also be triggered by exposure of flowers to external sources of ethylene, such as fruit and exhaust fumes. Flowers treated with chemicals which either inhibit ethylene biosynthesis by the flower, or prevent the flower responding to ethylene, last longer. At present, the most widely used of those chemicals is silver thiosulphate, a polluting metal salt. (BINAS [after GMAC], 1995).

In the early 1990s, Florigene produced a novel form of carnation modified to extend vase life. The genome of this carnation was altered in order to suppress the activity of (or “silence”) the genetic trigger for the synthesis of ACC (1-aminocyclopropane-1-carboxylic acid), the immediate precursor to ethylene. The addition to the genetic material of an additional, truncated ACC synthase encoding gene was found to inhibit the expression of the native ACC synthase gene and thus suppress the synthesis of ACC and ethylene (Agbios 2001).

In 1994 the GMAC granted the company a licence for the commercial release of this carnation line in Australia (Chandler, 1996; Foster, 2001: 22) and the EU gave Florigene commercial planting approval in 1998 (Foster, 2001: 77). According to the published record of the OGTR, however, the company did not seek OGTR approval to extend the commercial licence that had been granted by the GMAC when it expired in June 2003 (OGTR, 2003d: i; OGTR, 2007).

The explanation for what appears to be a decision to discontinue commercial activity in respect of this carnation seems to lie in inherent limitations to the advantages it offers. Dr John Mason, who heads Florigene's research team, has conceded that while the GM long-life carnations can reduce labour inputs and chemical hazard, preservatives are as effective as ethylene inhibition in extending vase life (Ryan, 2003). Consequently, unless biotechnology can offer other, significant advantage(s), such as reduced cost or markedly longer vase life, in a market such as Australia where chemical treatment is quite acceptable, a GM product is unlikely to compete successfully. In Holland, where use of the preservatives in question is no longer legal, Florigene's GM extended vase life carnation has been approved since 1998 (DEFRA, 2007; Ryan, 2003).

In 2000, on the verge of bankruptcy, Florigene was sold to Nufarm, which provided the funds necessary to maintain its research projects (Ryan, 2003). In December 2003, it was taken over by Suntory Limited, a Japanese brewing concern that had had a financial interest in Florigene since 1990 (Florigene, 2007c).

Chapter 7.

THE CASE OF GENETICALLY MODIFIED POPPIES

Papaver somniferum, or the opium poppy is probably best known as the source of the illicit narcotics opium and heroin, which have long been used and abused as highly potent drugs of pleasure. In most parts of the world, the cultivation and trade of this plant and its products is strongly discouraged and severe penalties, including capital punishment, are applied to the opiate trade.

However, as a rich source of alkaloids with important pharmaceutical applications, mostly in pain relief, it is also a legitimate and valuable crop. It is cultivated in several countries, under the Single Convention, a United Nations regulatory regime that sanctions and coordinates production and is primarily intended to ensure minimal illegal diversion of product. In Australia, the crop is commercially grown only in Tasmania, in compliance with a ministerial agreement between the States and the Commonwealth Government and according to the terms of the international arrangements. (EGGT, 2001:4; Fist, 2001: 2).

Background to the Modern Opium Industry

The opium poppy is a member of the papaveraceae family, which is comprised of about 28 genera and 250 species (University of Iowa, 2006). According to Paul Schiff, Professor of Pharmaceutical Sciences at Pittsburgh

University, the word “opium” is derived from the Greek words *opos* for “juice” and *opion* for “poppy juice” (Schiff, 2002: 186). The name of the genus, *Papaver*, is Greek for “poppy” (University of Iowa, 2006) and is suggested to have been derived from the Assyrian name for poppy juice *aratpa-pal* (Schiff, 2002: 186). The species name, *somniferum*, means “sleep inducing” in Latin (University of Iowa, 2006). It is one of the oldest recorded medicinal plants¹ and probably originated in Asia Minor² (Schiff, 2002: 186).

¹ Although logic suggests that preferential selection of higher opiate poppy strains would have been inevitable, the extent to which human intervention is responsible for the evolution of the opium poppy plant as a source of concentrated narcotic is unclear (University of Iowa, 2006). It is also not certain when it was first cultivated or whether it was originally valued for its seeds or its opiate content (Brownstein, 1993: 5391; Schiff, 2002: 186).

² Ancient sources such as Homer (850 BC) are ambiguous in respect of the early use of opium (Brownstein, 1993: 5391; Schiff, 2002: 186), although it is “frequently mentioned in Greek mythology” (Schiff, 2002: 186). US medical researcher M J Brownstein writes that, nonetheless, there exists a consensus among scholars that opium has been cultivated and used as a drug for at least several thousand years (Brownstein, 1993: 5391).

“There is general agreement that the Sumerians who inhabited what is today Iraq cultivated poppies and isolated opium from their seed capsules at the end of the third millennium BC. They called opium “gil” the word for joy, and the poppy “hul gil,” plant of joy. It appears that opium spread from Sumeria to the remainder of the old world”. (Brownstein, 1993: 5391).

Five thousand-year-old tablets describing “the cultivation of the opium poppy, including the collection of its juice early in the morning, with the subsequent production of opium” were discovered at Nippur, a Sumerian spiritual centre (Schiff, 2002: 186). It is conjectured that opium’s original function was in religious ceremonies.

“At first opium may have been employed as a euphoriant in religious rituals ... [and] knowledge of its use may have been confined to priests representing gods who healed the sick and gods of death as well”.(Brownstein, 1993: 5391).

Opium poppies were cultivated in ancient Egypt, but:

use of opium was generally restricted to priests, magicians and warriors and was associated with religious cultism. Thoth, the Egyptian god of letters, invention and wisdom was said to have instructed mortal beings about opium preparation, while the goddess Isis was said to have used opium as a headache remedy for the god Ra. ... Opium became a well known drug of Egypt, with its various preparations being concentrated in certain geographic regions. (Schiff, 2002: 186).

General pharmaceutical use of opium by the ancient Egyptians is also recorded. According to the *Ebers Papyrus* (a long medical document written around 1500 BC), pulped poppy head mixed with fly excrement “found on the wall” was an effective calmative for crying children (Brownstein, 1993: 5391).

Both Hippocrates (c 400 BC) and Theophrastus³ (c 300 BC) were familiar with the process of opium extraction and its medicinal use (Brownstein, 1993: 5391; University of Iowa, 2006), but the Greeks also found ways of applying opium in more sinister ways than just as a tonic, a sedative and painkiller. “The life terminating properties of opium were well known, and

³ The ancient Greeks:

“regarded opium as a symbol of consolation and oblivion, and crowned all of their nocturnal gods with a wreath of poppy blossoms. This was in concert with their belief that sleep was the greatest of all physicians and the most powerful consoler of humanity”. (Schiff, 2002: 186).

opium and hemlock were a commonly used combination for the execution of condemned individuals”⁴ (Schiff, 2002: 186).

According to Brownstein, by the 8th century AD, Arab traders had taken opium to India⁵ and China⁶, (Brownstein, 1993: 5391), although Schiff (2002: 187) dates its arrival in China somewhat later, “sometime between the 11th and 13th centuries”. Later, during the second half of the 18th century, opium production became a major commercial enterprise for the East India Company, supplying rampant opium addiction in China. A heavy, but illicit trade was developed via Canton, with a strongly isolationist China, mostly in

⁴ The dangers (or uses) of overdose, as well as the medical virtues of opium were passed on to the Romans. Pliny the Elder and his Greek contemporary, Dioscorides, a physician and pharmacologist, both warn of its lethal potential (University of Iowa, 2006) and, according to Pliny, Nero used a variety of plant poisons, including opium, to “eliminate enemies” (Schiff, 2002: 186).

⁵ Opium cultivation and use had been established some centuries earlier in India (Brownstein, 1993: 5391; Schiff, 2002: 187) where it was traditionally used to make a beverage, opium water, which was offered to guests. In the absence of more efficient alkaloid extraction methods, the whole head of the poppy was usually crushed and mixed with wine, honey or water for immediate consumption (University of Iowa, 2006).

⁶ In China, initially it was “principally used by the elite for the control of dysentery” (Schiff, 2002: 187), but in time it became a serious problem. After tobacco was introduced to Europe from the Americas in the 15th century, sailors took it to the East where it quickly became popular. However, the last Ming emperor, Tsung Chen, considered it to be evil and in 1644 it was banned. This action resulted in the Chinese people gradually extending their tobacco with opium, in increasing proportions until the tobacco was eliminated. By 1700 about 25% of the Chinese population were smoking opium (Schiff, 2002: 187).

exchange for tea and silk (Schiff, 2002: 187). In 1839 a new (and uncorrupted) viceroy in Canton seized and destroyed 2.6 million pounds of opium, sparking the first Opium War, which the Chinese lost. The price China paid for peace was to cede Hong Kong in perpetuity to Britain and to make reparation of 21 million pounds for the lost opium⁷ (Schiff, 2002: 187). The opium trade flourished until 1913 when changing morality in the West led to Britain bringing it to an end. Widespread opium cultivation and abuse continued in China until it was eradicated through a rigorous campaign after the communist revolution of 1949 (Schiff, 2002: 187).

Opium reached all parts of Europe between the 10th and 13th centuries (Brownstein, 1993: 5391), “mainly as a part of various mixtures that contained numerous ingredients”⁸ (Schiff, 2002: 187). Addiction became evident everywhere the drug was taken and descriptions of “drug abuse and tolerance” dating from the 16th century establish that problems were

⁷ The second Opium War and, eventually, the Boxer Rebellion that followed led to the extraction from the Chinese of further territorial and trade concessions to the West and the opening of the country to foreign influence (Schiff, 2002: 187).

⁸ One of the more significant medicinal uses of opium during the Middle Ages in Europe was in the preparation of *spongia somnifera* or “soporific sponges” (sponges steeped in a mixture of opium and other substances), which were used as a primitive local or general anaesthetic during surgery. (Brownstein, 1993: 5391). Thomas Sydenham, the “father” of English medicine, promoted laudanum as a treatment for the plague and is credited with introducing opium to Britain in the 17th century. His faith in its efficacy, however, appears not to have been complete as he is said to have fled the Great Plague of London in 1665 (Schiff, 2002: 187).

occurring in societies as diverse as those in England, Germany, Turkey and Egypt (Brownstein, 1993: 5391).

Schiff claims that after initial popularity, opium use in Europe decreased greatly “due to toxicity” (2002, 187) only to rise again after Paracelsus, a Swiss physician, chemist and alchemist, re-popularised it as the analgesic laudanum (effectively and more correctly, tincture of opium) a drug produced by dissolving opium in wine. It became commonly available and was freely used as an analgesic, a sedative and as a general remedy for diverse medical complaints (University of Iowa, 2006). Laudanum became notorious for its abuse in the 19th century, particularly by those in poetic and other artistic circles⁹. (Schiff, 2002: 187).

Morpheus, a Greek god of dreams, provided the inspiration for the name for morphine, the “narcotic principle of opium” (8% to 17% of opium gum), which was isolated in 1806 by a young German pharmacist, Friedrich Serturmer (Brownstein, 1993: 5391; Schiff, 2002: 189). Apart from greatly advancing human knowledge of opiate chemistry, Serturmer’s work was a

⁹ Laudanum is still made, although it is now “infrequently” used (Schiff, 2002: 188) It is now known as “deodorised opium tincture” and is standardised at “10 mg/ml of anhydrous morphine” or “approximately 20 percent ethanol and 10 percent opium” (Schiff, 2002: 188).

major step forward for the practicalities of delivering anaesthetic with precision and predictability¹⁰. Moreover:

Pure morphine ... could be made in large amounts. After the invention of the hypodermic syringe and hollow needle in the 1850s, morphine began to be used for minor surgical procedures, for post-operative and chronic pain, and as an adjunct to general anaesthetics. (Brownstein, 1993: 5391).

However, although hypodermic needles permitted “rapid analgesia”, they were not mass produced for some time, so the older, far less effective substances and methods prevailed in anaesthesia for some time. During the Franco-Prussian War and the American Civil War, “morphine was commonly placed directly on flesh wounds”, but opium, either as the tincture or pills was the more usual anaesthetic (Schiff, 2002: 189).

The Union Army used 2.8 million ounces of opium tincture and powder and about 500,000 opium pills. It is even reported that an officer would sometimes sit on his horse while men licked opium off his glove. At the termination of the Civil War, many wounded veterans had become addicted to morphine and their continued dependence on the drug was dubbed the “soldiers’ disease”. (Schiff, 2002: 189).

So while the isolation of morphine advanced analgesic medicine beyond the medieval technology of opium pills and laudanum, morphine itself had been

¹⁰ Serturmer asserted in a paper written in 1806 that morphine was the “first representative of a new class of organic bases called “vegetable alkalis” that ... formed salts with both organic and inorganic acids” (Schiff, 2002: 189). Although his findings were at first disregarded, he continued his work and in 1817 published a more detailed and conclusive account of his investigations, which established the presence of nitrogen in morphine, in addition to carbon, hydrogen and oxygen. The following year another German pharmacist, Karl Meissner applied the term “alkaloid” to this group of compounds (Schiff, 2002: 189).

shown to be every bit as addictive and dangerous. The search for a safe and non-addictive opiate continued throughout the 19th and early 20th Centuries leading to the isolation of numerous other compounds, some of which are now quite important (Brownstein, 1993: 5391).

Coedine was first identified in 1833 by Robiquet, but it typically occurs in opium at a low concentration (between 0.7% and 2.5%), which was considered insufficient for commercial production. It is chemically very similar to morphine¹¹ and is usually produced now by the methylation of morphine (first achieved by Grimaux in 1881) (Schiff, 2002: 192).

In 1874 Alder Wright, a British pharmacist attempting to synthesise morphine in a non-addictive form, produced an analgesic compound that was claimed to be more potent than morphine without being habit-forming (Brownstein, 1993: 5391; Schiff, 2002: 191). It was named heroin in consequence of its apparently “heroic” qualities and was developed and marketed by Bayer as a cough suppressant in 1898. When its “highly addictive properties” became apparent, its use was restricted (Schiff, 2002: 191).

¹¹ The pharmacological functions of coedine are exactly the same as those of morphine, but it is less potent. About 10 percent of an administered coedine dose is biochemically converted to morphine, which is largely responsible for its analgesic effect (Schiff, 2002: 192).

Thebaine, although long known, became an alkaloid of increasing pharmaceutical importance around 1990. It is present in “standard” or traditional opium at a level of 0.1 to 2.5 percent and typically at less than 1 percent (Schiff, 2002: 191). It is not used therapeutically itself, but has considerable importance as “a substrate in the semi-synthesis” of analgesics and products used to treat opiate addiction (Schiff, 2002: 191). It is of a similar chemical structure to both morphine and codeine, but is a stimulant and convulsant rather than a depressant and relaxant (OKDHS, 2007; Schiff, 2002: 191).

The search for a synthetic alternative to atropine (a multiple-purpose alkaloid that is the major component of belladonna, the key product of deadly nightshade) led to the discovery in 1939 of pethidine, which is known as meperidine in the US (Brownstein, 1993: 5391). This has since become a very important analgesic drug in the treatment of severe pain.

Methadone, which has similar characteristics to morphine, was first synthesised in 1946. The peculiarities of the abstinence syndrome (or “withdrawal symptoms”) associated with this drug make it particularly suitable for use in the treatment of opiate addiction (Brownstein, 1993: 5391).

Methadone treatment may be continued over long periods, sometimes running into years¹² (Broekhuysen, 2000).

The Opium Industry

By the early 20th century, the failure to successfully regulate opium and rein in abuse had led to a general acceptance by governments that it would be necessary to control its production and distribution at an international level if intervention was ever going to be effective.

... the International Opium Commission was founded in 1909, and by 1914 thirty four nations concurred in their belief that opium production and importation should be decreased. After World War I, the Commission next met in 1924, with sixty two countries then participating. The League of Nations subsequently assumed this role, and all signatory countries agreed to pass laws and regulations to limit the import, sale, distribution, export and use of all narcotic drugs to medical and scientific purposes. Presently the cultivation of the opium poppy is internationally regulated by the International Narcotics Control Board of the United Nations . (Schiff, 2002: 187).

International regulation and the constraints it imposes, has been conducive to the establishment of a secure and advanced agricultural industry in a number of economically advanced nations that produces pharmaceutical alkaloid on a large scale. With the exception of the illicit trade, the remaining traditional

¹² It is a good substitute for morphine and heroin, which can rapidly provoke intense symptoms of withdrawal in addicts. "Methadone reduces the cravings associated with heroin use and blocks the high from heroin, but it does not provide the euphoric rush. ... Withdrawal from methadone is much slower than from heroin" (Broekhuysen, 2000). It is possible for "stable methadone addicts to lead reasonably normal lives, and the drug can be withdrawn when they no longer desire to use it" (Brownstein, 1993: 5391).

opium “gum” production¹³ is now almost completely confined to northern India¹⁴ (Schiff, 2002: 188).

Traditional opium gum production is astonishingly laborious and far too inefficient for an industrialised international economy. As early as the beginning of the 19th Century, following Serturmer’s discoveries, direct extraction of morphine from poppy capsules, became an important goal of the emerging pharmaceutical manufacturing sector (Bayer, 1961). Although this

¹³ Schiff, (2002: 188) describes conventional production as it is still carried out in India. The cycle begins in late Autumn (November) when seeds are sown. In early spring the plant are thinned to a spacing of around 60 cm and flowering occurs in April-May. By mid-summer the 5 to 8 capsules per plant are mature and the latex is collected via 4 to 6 fairly precise horizontal incisions made in each head. These incisions breach the laticiferous ducts, without penetrating the endocarp, and the white latex seeps out. It dries and darkens to brown or black on the outside of the capsule in the sunlight and air. Early the following morning while the cool temperature keeps it solid, the raw opium is harvested with an iron scraper or knife. The entire slitting and harvesting operation is repeated three or four more times (Schiff, 2002: 188). The gathered material is kneaded into balls, wrapped in poppy leaves and either air-dried, or placed in vessels with perforated bases through which the water content can drain. Further drying occurs at central government collection stations until the water content is reduced to about 10%. After this, the opium is moulded into 5kg cakes and packed in polythene bags for shipping to processors (Schiff, 2002: 188).

¹⁴ Some traditional cultivation and collection still occurs in China and North Korea, but “is reputed to be for exclusive domestic medical use” (Schiff, 2002: 187). According to the UNODC (the United Nations Office on Drugs and Crime) China was to have ended its production at the end of 2001, but it is unclear whether or not this has occurred as it still maintains opium production “estimates” (Ambekar et al, 2005: 31). Japan also practises a low level of opium gum production “to maintain the technology” (Ambekar et al, 2005: 31). The INCB (International Narcotics Control Board) reports that for the year 2005 China produced 12.7 tons of opium and North Korea produced 340 kg (INCB, 2006: 72).

was technically achieved at an experimental level relatively quickly, in the 1820s, it remained an uneconomic proposition compared to morphine production from opium until 1925 (Bayer, 1961).

In that year, a young Hungarian, Janos Kabay, developed a means of directly extracting morphine from poppies reaped at petal-fall, while they were still green¹⁵. The greatest disadvantages of his method were the loss of the alkaloid-free but valuable seed, the need to process the poppies on the farm and the shortness of the optimum harvest period. By 1931, when he patented his process, however, Kabay had discovered that the alkaloid and seeds were both recoverable after the poppy heads had matured and dried. By means of relatively minor modifications to his original process, it was possible to accommodate the dried material, which meant that he was able to overcome the three disadvantages at once (Bayer, 1961).

This revolutionary process took the opiate industry from the arduous manual technology of ancient slave societies to 20th Century mass production in one bound, making industrial-scale, temperate-climate opiate production

¹⁵ In order to avoid transporting the heavy crops, he produced a mobile “extracting machine” that could be taken to the farms where the crop was grown and operated on-site (Bayer, 1961). After preliminary chopping, crushing and pressing, the material was fed into the machine and continuously agitated in an extraction fluid (sodium bisulphite and water). All retrieved liquid was transported to his factory where it was reduced to a stable, “pasty substance [with] a morphine content of between 0.4% and 0.8%”, which could then be further reduced with ethanol and fractionated as required (Bayer, 1961).

immediately possible. Although the efficiency of the extraction process has been greatly improved since, it is most critically upon Kabay's innovations that the viability of the present day industry and the availability of affordable analgesics depend. Within three years of the commencement of Kabay's small-scale, family operation in the late 1920s, Hungary, which had previously imported morphine, had become a modest exporter (Bayer, 1961).

A League of Nations committee visited Kabay in 1934 and the technology was soon taken up in Switzerland, Poland and Czechoslovakia (Bayer, 1961). Kabay had struggled financially to bring his ideas to fruition and had endured public prejudice and vilification for producing a drug of addiction in Hungary. He died in 1936, successful, but exhausted, having seen the embryonic industry through to the point of economic viability. However, the war and then the cold war intervened and although Hungarian morphine production initially grew quite rapidly in the post-war years, by 1958 the Netherlands was the only country outside the Soviet bloc that was using the technology (Bayer, 1961).

In post-war, Soviet Hungary, morphine seems to have been treated as no more than a (possibly) profitable and useful byproduct of the poppy seed industry, rather than the bedrock of an emerging industry in its own right¹⁶.

¹⁶ Hungary had traditionally cultivated poppies on a large scale for poppy seed production, but the straw had been regarded as waste and used as fuel or animal bedding (Bayer, 1961). The seeds themselves and their oil (comprising 40% to 50% of their weight) are valued for

The established seed producers favoured low-alkaloid stock that had been selected on the basis of qualities such as seed appearance and oil yield¹⁷ (Bayer, 1961; Mackenzie, 2004: 923). Hungary is now a relatively minor producer of alkaloid and is probably responsible for less than 5% of world production¹⁸ (INCB, 2002: 77 - 82).

The Tasmanian Poppy Industry

The genesis of the Tasmanian poppy industry was a search by British alkaloid producers to identify a satisfactory location for a secure poppy straw industry. Following WWII, Edinburgh companies, J.F. Macfarlan and T.&H. Smith, had found the opium supply from India and Turkey “erratic” and had decided to jointly work towards the establishment of a more reliable source

their culinary qualities, but the oil also has a quick drying nature and was in demand for use as a solvent for oil paint pigments (Bayer, 1961).

¹⁷ A Soviet era Hungarian official, Dr Bayer, claims in a 1961 paper that “Since 1951, several experiments have been made for the purpose of selecting an improved variety of poppy plant with a morphine content higher than the 1951 average” (Bayer 1961), but gives little further detail. This was at a time when competitor countries, with their eye on the lucrative and growing alkaloid market, were intent upon breeding new strains of poppy with increased alkaloid content (Mackenzie, 2004: 923). Hungary, through its failure from the outset to support and develop Kabay’s remarkable technology, lost and never regained the opportunity to lead the medical opiate market.

¹⁸ A 2002 report emanating from Budapest University of Technology and Economics claims 10% of world morphine production for Hungary, but is coy about the more critical facts and figures. Its content strongly suggests that the climate and the state of agricultural technology in Hungary are considerably less than optimum (BUTE, 2002 & 2004: 38).

of raw material, originally intended to be in the UK¹⁹ (Mackenzie, 2004: 923; Rogers, 2004: 14). There is no reason to believe that this initiative was other than a responsible, long-term strategy based on informed and considered judgment²⁰. These two companies, which later merged to form Edinburgh Pharmaceutical Industries Ltd, were long-established industry leaders, steeped in the science of opium chemistry.

The core business of the Macfarlan and Smith companies for more than 100 years was the manufacture of alkaloids derived from opium and their leading position in the trade was the result of meticulous development work to maximise the yield of morphine from the opium and the efficiency of its conversion to coedine. (Jack, c1995: 1).

In 1951 a botanist, Mr Stephen King, was employed by the manufacturers to investigate the scientific matters pertinent to the establishment of a domestic poppy straw industry. More specifically, his brief was to develop new strains

¹⁹ They had apparently been advised by the Home Office to consider the use of locally grown poppy straw rather than imported opium gum, on the grounds that potential political instability in the traditional opium-producing areas might be a threat to security of supply (Mackenzie, 2004: 923). Both the volume and the consistency of the opium supply would have been increasing concerns to producers gearing up their scale of operations in the rapidly expanding post-war economy.

²⁰ The broader political environment of the times had been shaped by a long and painful war and was dominated by the threat of a worse one. In this context, the reliability of emergency pharmaceutical supplies, such as opiate-based analgesics, would necessarily have become a significant security issue in the event of any hostilities or even serious political tensions. To this extent, the eventual choice of Tasmania must be considered to have had some significant international political implications.

of *Papaver somniferum* with much increased alkaloid levels and attractive seed characteristics that could be grown in “the south and east of England”²¹ (Mackenzie, 2004: 923).

The project succeeded in its major goals of increasing “the morphine content to a viable level while maintaining the desirable colour and quality of the poppy seeds”, but it became apparent that the British climate was far too wet and cool to support commercial crops. Rain frequently leached the morphine out of the ripening poppy heads (Mackenzie, 2004: 923). In King’s words:

From 1951 to ’55 we tried to grow poppies in England, but it was dreadful. We used to plant crops, then ask the farmers to burn them because the morphine content wasn’t worth extracting. It was just too wet. (Rogers, 2004:14).

The planted area in England never exceeded 300ha and the effort to grow poppies there was abandoned in 1957 (Rogers, 2004: 14; Watson, 1999: 9076).

²¹ The breeding program that he put in place was bold. It attempted to overcome a primary, natural constraint on the work of crop-plant breeders by taking advantage of the growing seasons of both the Northern and Southern Hemispheres. This involved shipping seed between England and New Zealand as soon as it was harvested, in order to produce two new generations of poppies each year, effectively halving the period of time required to develop a suitable variety (Mackenzie, 2004: 923). King, who ultimately received an OBE for his work:

“...played the leading part in the project, but he was ably supported by scientists in Edinburgh who carried out thousands of assays on individual poppy capsules and devised efficient extraction methods for the alkaloids.” (Jack, c1995: 1)

Once the UK was excluded as a suitable agricultural environment for poppies, it became necessary to find an alternative that satisfied the various determining criteria. In a 2002 interview with "Tasmanian Country", Stephen King briefly referred to the process of elimination that ultimately led to Tasmania remaining the only viable option. "We had ruled out America, because America wouldn't have the poppies ... South Africa was too unstable, ditto for the Mediterranean, which left the southern seaboard of Australia" (Rogers, 2004: 14). Clearly, political considerations were a major constraint, overriding all the practical and agronomic limitations.

For four years, beginning in 1960, State Government poppy trials were conducted in NSW, Western Australia, South Australia and Tasmania (Watson, 1999: 9076). Tasmania was originally disregarded entirely, on the basis of rainfall statistics that suggested it was too wet for poppies. It was only reconsidered when the reconnoitring King found himself with a spare week after the Victorian Minister for Agriculture had refused to even let him into his office to discuss trials in that state, on the grounds that poppies were "a dangerous drug crop" (Rogers, 2004: 14).

The mainland states were eventually found to be less suitable "for one reason or another" (Rogers, 2004: 14) and in 1964, just prior to being absorbed by

the Glaxo group²², the Edinburgh Pharmaceutical Company decided to invest in Tasmania²³ (Mackenzie, 2004: 924; Rogers, 2004: 14). Now, in addition to pursuing yield improvement, the breeding program also needed to develop strains of poppy suited to Tasmanian conditions (Mackenzie, 2004: 924).

Alkaloid content was improving by around 5% a year and in 1969, almost twenty years after the breeding program began, a commercially viable poppy cultivar was identified. (Rogers, 2004: 14; Watson, 1999: 9076). In the 1964-1965 growing season, 17 growers had produced 140 kg of alkaloid from a total of 52 hectares, but by 1971-1972 the company was producing “sufficient morphine to supply the needs of Australia as well as New Zealand” (Mackenzie, 2004: 924; Watson, 1999: 9076).

²² Glaxo was clearly not committed to the project in the same way that the original investors had been and, it seems from the record left by King that it was prepared to abandon the whole venture if it became too great a drain on resources. During these last, critical developmental years, the enterprise was operated “on a shoestring.” (Rogers, 2004: 14). King later recalled: “All the time, ... [the Australian head of Glaxo] was ready to chop it. We borrowed everything and we rented everything, which made it hard” (Rogers, 2004: 14).

²³ Trial experience had shown that its climatic conditions would suit the crop and that the free-draining Tasmanian krasnozems (now known as red ferrosols) made something of a virtue of the high rainfall, in providing insurance against drought (Rogers, 2004: 14). These soils are also very fertile, meaning that yield potential was high and the cool Tasmanian nights were found to conserve plant energy through reduced cell respiration, thus enhancing morphine synthesis (Rogers, 2004: 14).

There remained a number of practical problems to be dealt with before true commercial production could begin. These included the widespread soil acidity, the need for economic weed and disease control, the need for suitable harvesting technology and the need for processing infrastructure (Mackenzie, 2004: 924; Rogers, 2004: 14; Watson, 1999: 9076). In 1970 a straw preparation factory was constructed in the north of the state, at Latrobe, but Glaxo decided not to carry out alkaloid extraction in Tasmania. It already possessed a dried milk factory at Port Fairy in Victoria where an extraction facility was developed (Mackenzie, 2004: 924; Watson, 1999: 9076). Glaxo's pelletised poppy straw is still shipped there from Tasmania for downstream processing (DFiWE, 2004).

A second company, Tasmanian Alkaloids (now a Johnson and Johnson subsidiary) began operations at this point,²⁴ but is wholly located in Tasmania and has a substantial plant at the northern town of Westbury, where it produces coedine, oxycodone, buprenorphine and other APIs (Active

²⁴ Glaxo's decision to locate the value-adding stage of the production process outside Tasmania, and to thus deprive the State of much of the industry's economic benefit, appears to have provoked the ire of Tasmanian authorities. According to King, the Tasmanian Department of Agriculture "bent over backwards" to assist the establishment of the now dominant competitor, Tasmanian Alkaloids in the early 1970s. His view was that the newcomer was able to take full advantage of the research and other work that he had done over a twenty-year period, without cost. "We had no way of protecting our varieties or our methods" (Rogers, 2004: 14).

Pharmaceutical Ingredients) (EIU, 2005:113; Fist, 2001:2). Its web page states that it

spends over \$20 million each year in salaries, wages and related costs ... purchases up to \$45 million of poppy crop from farmers throughout Tasmania ... [and] \$28 million of materials for processing and other services such as engineering, contracting, power etc., the majority of which is sourced from Tasmania. (Tas Alkaloids, 2007).

This means that in a good year the company is spending a total of almost \$100 million in Tasmania, a very significant amount in the context of the size of the State's economy.

A third Tasmanian alkaloid manufacturer, TPI Enterprises was founded in 2004 and began crop trials (3 hectares) and manufacturing tests the following year. In 2006 it successfully applied for narcotics manufacturing, import and export licences in relation to the trial crops, from which it manufactured samples for prospective customers. It claims to have developed "alternative Thebaine poppies and enhanced extraction techniques" (TPI, 2007) based on a "unique solvent-free process" (IRIS, 2007a). It has built a small processing plant and has conducted a fairly public campaign to gain licences to grow 1,200 ha of poppies and to produce 10,000kg of alkaloid as a first level of production in a four-stage plan. GlaxoSmithKline has engaged the managing director of TPI in lengthy litigation, centred on allegations of intellectual property theft and breaches of the *Trade Practices Act* (Grant, 2007; IRIS, 2007a; TPI, 2007).

The Tasmanian Agricultural Economy

Since the politics of GM technology and the existing GM ban in Tasmania are related to a perceived potential for food markets and industries to be damaged by any association with GM crops, an elementary understanding of Tasmanian primary industry is necessary. The value of total Tasmanian food exports averages a little under \$1.5B with two thirds of that figure (about \$1B) being sold in mainland Australian markets and the remaining third (around \$450M) being exported (DPIW, 2006: 18).

According to the official figures released by the Australian Bureau of Statistics (ABS), in the year 2004-2005, Tasmanian Agriculture generated farm-gate income of \$903M, or 3% of total Australian agricultural income (ABS, 2006: 8). This was a production increase of 5% over the previous year. Of this total, crops were responsible for \$385M or 42.6%, which represented a slight fall in value. Livestock accounted for \$518M, or 57.4% of the total, a significant increase. Beef was valued at \$188M, mutton and lamb, \$45.8M, whole milk, \$185M and wool, \$64.5M (ABS, 2006: 8).

Of the major crops, the largest, potatoes, comprised 19.6% of total Tasmanian crop value, earning \$75.5M. Apples (11.6%) were worth \$44.6M (a steep rise), onions (6.2%) were valued at \$24.0M (a sharp fall), carrots (5.9%) rose slightly in value to \$22.9M and returns from grapes (3.8%) fell to \$14.8M (ABS, 2006: 8).

According to the Tasmanian Infrastructure and Resource Information Service, in 2003-2004, when farm-gate income was \$856.9M, the total value added economic benefit to the state flowing from agriculture, was \$1,765M, almost precisely twice the value of the bare farm-gate figure (IRIS, 2007b).

Many Tasmanian industries are highly dependent on the Tasmanian Freight Equalisation Scheme (TFES), which limits the cost of freight of certain goods across Bass Strait to the equivalent of the road transport cost over the same distance, in order “to offset shipping costs to interstate markets” (IRIS, 2007c). The vegetable growing sector, which is chiefly geared to the production of vegetables destined for processing as frozen and canned food, is not the least of these. In 2004-2005, the TFES assisted the northbound freight of fresh, frozen and processed vegetables to the extent of \$18.75M (TFGA, 2006: 10; IRIS, 2007c). However desirable this might be in social and political terms, it is an interference that masks the true market value of the produce and imposes costs on other sectors of the economy.

Where the cost of freight constitutes a significant percentage of the market value of goods, the TFES subsidy clearly may be critical to industry profitability. The Tasmanian Farmers and Graziers Association (TFGA), in a 2006 submission to the Productivity Commission, wrote that

TFES assistance payments on vegetables shipped across Bass Strait represent a major component of total payments and their removal would impact heavily

on farm income and viability. This would in turn impact on factory viability and closures would be likely to occur (TFGA, 2006:10).

Tasmanian vegetable producers have also been increasingly threatened by downward pressure on prices, as progressive abolition of trade barriers has exposed them to competition from imported vegetables and vegetable products. A high-profile national campaign by Tasmanian growers, the “Fair Dinkum Food” campaign has, with the support of the State Government, attempted to strengthen the market position of farmers by promoting Country of Origin Labelling (CoOL) (F&A, 2005).

Sales of potatoes, traditionally a very important crop for Tasmania, still account for more farm-gate income than any other crop and are responsible for almost half of the farm-gate value of all vegetable crops (41.9% in 2003-2004) (IRIS, 2007c). About 80% of harvested potatoes are processed, 10% are sold fresh and 10% are grown as seed crops (DPIWE, 2004b: 122).

The potato crop value has, however, consistently declined over a reasonably long period, decreasing from close to \$85M in 1996-1997 to a 2004-2005 value of \$75.5M (ABS, 2006: 8; IRIS, 2007c). Processor cuts to contracts in 2005, arising from more competitive New Zealand producers taking market share have further eroded it²⁵ (TFGA, 2006: 7).

²⁵ Tasmanian vegetable farms are mostly of small size, which has important connotations for viability when farmers are engaged in direct competition with very large operators. At the height of the furore that arose when New Zealand potato growers began to take Tasmanian

Quantification of the value of downstream processing of potatoes is apparently not straightforward as estimates of the size of the financial gain vary, but it appears to increase the farm-gate figure by 2.5 to 3 times. For the year 2003-2004, the total improved (“packed and processed”) value of the \$75.3M potato crop (in forms such as frozen chips) was calculated by the Tasmanian Department of Primary Industries and Water to be \$205M (IRIS, 2007c; TFGA, 2006: 15).

According to statistics published by Tasmania’s Department of Primary Industry, over the years 1998 to 2005, approximately 15% of Tasmanian potatoes and potato products were sold locally, around 80% were disposed of in mainland Australian markets while only 5% were exported (DPIW, 2007; DPIWE, 2004b: 127). These figures were very consistent over this period.

During the period 1998 to 2002, 100% of processed peas, carrots and broccoli, and 95% of processed beans were disposed of in Australia. The

domestic markets, Greg Barnes, a local political commentator, pointed out that Tasmanian farms are simply too small to compete in a globalised commodity market. While 13 New Zealand farms are able to produce 80,000 tonnes of potatoes, it takes 450 Tasmanian farms to grow the same amount (Barnes, 2005). On this basis, long term agricultural commodity production in Tasmania, by some sectors of the industry at least, appears to be unsustainable, a view that is supported by buyer behaviour in the market. A profitable future for Tasmanian growers would seem to require new crops, new technologies, a massively increased scale of operation or a combination of these.

remaining 5% of beans was exported (DPIWE, 2004b. 132-133). Over the same period, 72% to 85% of an onion crop that typically had a total farm gate value of about \$8M was exported, with most of the remainder being sold in mainland Australia (DPIWE, 2004b: 137). Some much smaller niche markets for fresh vegetables, worth a total of up to \$15M annually were also reported over this period, with about half being sold on the mainland and the other half more or less split between local and export sales (DPIWE, 2004b: 142). The salient point here is that while export markets may be economically important to individual producers and wholesalers, they actually constitute quite a small percentage of the entire vegetable market.

Apple and pear production and disposals have remained fairly constant at around \$50M since the early 1990s, although exports fell from 30% to a steady 25% of total sales over the ten years from 1991 to 2001 (DPIWE, 2004b: 52). Exports in 2003-2004 are listed by DPIW as being worth \$10M, (actually \$9.67M) with the less-than-convincing suggestion that this very low figure was due to "very strong domestic demand" (DPIW, 2006: 18). In 2004-2005 apple and pear exports amounted to \$13.04M but fell to only \$4.92M in the following year, according to Department of Economic Development statistics (DEC, 2007: 1).

Tasmanian Poppy Production and State Government Policy

Opiates are produced in Tasmania²⁶ according to a legal arrangement with the United Nations, under the terms of the milestone 1961 treaty, the Single Convention on Narcotic Drugs (a rationalising, regulatory instrument, usually referred to as the “Single Convention”). The Tasmanian poppy growing industry is hence advised, regulated and monitored by the Tasmanian Poppy Advisory and Control Board which operates through a system of licences, reporting, inspection and surveillance²⁷ (DPIWE 2004: 4; EGGT, 2001; 5).

²⁶ Poppy production in Tasmania is largely concentrated in the highly fertile north-west of the state where intensive farming of various crops is carried out in the robust red ferrosols that occur there. Approximately 50% of the total alkaloid yield is drawn from this area and the remainder is grown in numerous localities in the north, the midlands and south (DPIWE, 2004: 2).

²⁷ The OGTR succinctly summarises the arrangements:

“The Single Convention on Narcotic Drugs 1961 (as amended by the 1972 protocol) strictly regulates worldwide production, manufacture and sale of narcotic based drugs. Australia is a signatory to this convention. The Convention requires stringent control and supervision of the growing and production of opiates, with the aims of combating drug abuse and illicit traffic, preventing diversion of illicit opiates, and ensuring adequate supply of medical and scientific use.

In order to meet Australia’s commitment to the Convention, the Poppy Advisory and Control Board was established. The Board, an agency of the Department of Justice, Tasmania, is the State Government authority responsible for licensing of poppy crops in Tasmania. The Board regulates poppy cultivation in Tasmania using the powers derived from the *Poisons Act 1971* (Tasmania) to regulate the industry. Import, export and manufacture of the drugs derived from the poppies, are licensed by the Commonwealth under the Narcotic Drugs Act 1971 (Commonwealth).

The board is also responsible for coordinating security and control of the industry. Because of the narcotic content of plants, strict control measures are

Within the State, the Tasmanian poppy industry has for some years been afforded a status in terms of its global standing that sometimes verges on the mythical. State Governments of both persuasions have long exploited its successes for political purposes, but recent oversupply in the international market has caused some hurt to the Tasmanian industry and become a potential political embarrassment of some magnitude. The rise of anti GM sentiment at about the same time has further complicated this problem because the scientifically progressive needs of the alkaloid industry are now in conflict with environmentalist demands for precautionary action. Unsurprisingly, the messages about GM technology and the fate of the poppy industry emanating from the Tasmanian Government and its instruments have become unclear and confusing.

Official²⁸ Tasmanian Department of Primary industries, Water and Environment (DPIWE) literature on the poppy industry records the standard claim that “Tasmanian production satisfies about 50% of licit world opiate requirements” (DPIWE, 2004: 5), an inaccurate assertion that is dispelled by reference to published INCB (International Narcotics Control Board)

maintained over all aspects of growing through to processing. Board field officers regularly patrol crops and liaise with the Tasmanian Police Poppy Task Force, which operates each season”. (OGTR, 2002: 15)

²⁸ Still published as current information at the time of writing in 2007.

figures²⁹ shown in Table 7.1 (INCB, 2002: 73). In only one year, 2002, has Tasmania exceeded 40% of the world's legally produced opiate. In that year it produced 237 out of a world total of 583 tons, or 41% of all production (INCB, 2006: 94-95).

Table 7.1

	Australia (straw)	Total Straw	Australia % of total straw	India (gum)	Total opiate	Australia % of all opiate
1998	90	257	35%	29	286	31%
1999	98	291	34%	118	409	24%
2000	152	289	52%	146	435	35%
2001	140	307	46%	85	392	36%
2002	237	493	48%	90	583	41%
2003	209	504	41%	63	567	37%
2004	140	423	33%	101	524	27%
2005	172	416	41%	41	457	38%
2006	150	402	37%	39	441	34%

Australian straw, world straw, Indian gum and total world opiate production in tons, 1998 to 2006. Standard rounding and standardisation³⁰ of figures applied. Source: INCB, 2002&2006.

In 2004 it was possible to claim that the Tasmanian production average for the previous four years (almost 47% of all poppy *straw* produced) was

²⁹ INCB statistics, which are the only freely available official figures, are assumed to be authoritative.

³⁰ Because poppy straw concentrations vary between countries, the INCB calculates values in terms of common denominator units called morphine or thebaine "equivalents" (INCB, 2006: 74). These are also applied to opium gum and make it possible for valid comparisons to be made between producers (INCB, 2006: 72).

nudging the 50% mark. But poppy straw does not comprise the whole market (INCB, 2006: 74-75; 94-95) and in order to arrive at this percentage, the figures for India, a very important traditional producer of opium gum, have to be excluded. While Australia's poppy straw statistic is no doubt of interest to the poppy industry, it is not relevant to total opiate production. The most obvious consequence of not including the Indian statistics in world opiate production totals is that the importance of Tasmania as a producer is exaggerated.

Of more genuine salience to the industry is the erosion of its overall market share since 2002. Tasmania still consistently dominates the thebaine sector of the market, producing well in excess of half the total every year (INCB, 2002: 73; 2006: 95), a fortunate factor that compensates for its slippage in the traditional morphine market. The percentages of the morphine market annually held by Australia from the 2002 peak year up to and including 2006 were: 34%, 31%, 21%, 30% and 23%, an average of just under 28% (INCB, 2006: 94).

Australia's alkaloid market share from 1989 to 2006 averaged 31.6% and between the introduction of thebaine poppies and 2006 it was slightly higher at 34.4%. In the three years from 2004 to 2006, Tasmania, on average, produced 33% of world total opiate and, less importantly, 37% of total poppy straw (INCB, 2002: 73; INCB, 2006: 74). These figures show that Tasmanian

alkaloid production over the longer time frame has actually been less than one third of world production. Since the introduction of the thebaine poppy it has amounted to a little more than one third. The uncertain market portion that lies between Australia's 1995 low of 19% and its 2002 high of 48% is variously accounted for by France, Spain and Turkey and a number of smaller producers (INCB, 2006: 74).

The Tasmanian Government's PACB asserts that poppy industry statistics should not be "available" "due to confidentiality requirements" (DPIWE, 2004; PACB, 2007) and so does not publish them. DPIWE³¹ and the Australian Bureau of Statistics also observe this edict, so unlike all other Tasmanian agricultural commodities, separate poppy statistics are not published. Specific statistics for recent Tasmanian poppy and opiate production are, however, readily available from other sources³², although the

³¹ Tasmanian Government sources of information on the poppy industry are uninformative in comparison to other major agriculture sectors. DPIWE figures in a table in its main poppy industry "backgrounder", quoting the value of the Tasmanian poppy crop, did not change between 2004 and 2007, even though the web page version claims to be regularly updated. The cells for "estimate of product quantity" remained blank over the same period. In July 2007 the most recently available statistics referred to the 2002-2003 season (DPIWE, 2004).

³² The INCB, for example, annually publishes a detailed analysis of poppy and alkaloid production for all producers of licit opiates, including Tasmania, entitled *Statistical Information on Narcotic Drugs* (INCB, 2005: 69-97). It includes production tonnages and planted areas but not monetary values. Although production levels and market share provide some guide, the absence of information concerning the value of Tasmanian alkaloid production limits the scope of industry analysis.

value of opiate production in recent years and individual company performances remain difficult to obtain.

The Tasmanian Agricultural Productivity Group's 2006 publication *Crop Protection Practices in Tasmania*, (TAPG, 2006: 5) puts the 2004-2005 farm-gate value of the State's poppy crop at "some \$50M" (which equates to 13% of total Tasmanian agricultural crop value). This relatively low figure is consistent with smaller crops over recent years, a trend that has usually been associated with a world alkaloid glut, which has arisen for complex reasons. In the four years 1999-2000 to 2002-2003, farm-gate values ranged between \$55M and 75M, with the peak value occurring in 2001-2002 (DPIWE, 2004).

However, the overall value of the crop to the Tasmanian economy, when both GlaxoSmithKline's poppy basic straw production and Tasmanian Alkaloids downstream processing is taken into account, amounts to much more than the bare farm-gate value might suggest. The value-adding component is generally reckoned to increase the farm gate value of poppies, by a factor of about 4. Thus, although detailed figures are not publicly released by the companies, the benchmark value of the poppy industry to Tasmania has, over a period of some years, consistently been quoted at \$200M by various authorities, reaching as high as \$250M per annum in the best years. (EGGT, 2001: 5; JSCGT, 2001: 30, 95; TDED, 2007). Although there is no reason to question the basic integrity of these round numbers, as unsupported claims,

they should be regarded as “ballpark” figures that are more likely to be overstatements than understatements.

At the industry’s peak, between the late 1990s and 2003, GlaxoSmithKline and Tasmanian Alkaloids together contracted some 1200 farmers to cultivate around 20,000 hectares of poppies annually for alkaloid production³³ (DPIWE, 2004: 1; Fist, 2002: 1). However, these numbers fell sharply after 2003 as a series of excellent growing seasons and major technological advances in Tasmania coincided with a surge in Indian plantings³⁴, leading to worldwide oversupply³⁵ (Fist, 2001: 8).

³³ Both processing companies claim 25% of the world opiate market, (GSK, 2007b; Tasmanian Alkaloids, 2007). Tasmanian Alkaloids also advertises itself as the “largest manufacturer of Active Pharmaceutical Ingredients in Australia”, the “largest exporter of Codeine in the world (UN statistics)” and “largest exporter of Thebaine in the world (UN statistics)” (Tasmanian Alkaloids, 2007b). GlaxoSmithKline claims that “each year” it “contracts approximately 800 farmers to grow nearly 10,000 hectares of poppy crop” (GSK, 2006), a claim that is simply not true. While this may have been correct for 3 or 4 years around the year 2000, it certainly was not in 2006-2007 when the entire Tasmanian crop was less than 10,000 hectares and Tasmanian Alkaloids made contracts for 7000 hectares of that.

³⁴ The surge in demand for thebaine encouraged huge production increases in India. The US “80/20” rule favouring trade with India was probably a big factor.

³⁵ This downturn in the opiate market coincided with State government suppression of GM crop development and cultivation. While it is not suggested that there is a causative link between the two, the ability of the industry to recover may well depend upon access to GM technology. Analysis of the industry is hampered by the behaviour of many institutions associated with alkaloid production, which tend to simultaneously “talk the industry up” and withhold information. In fairness to Tasmanian Alkaloids, which is not at fault, it is pointed out that it is categorically excluded from this generalisation.

Table 7.2

Year	INCB		Police		DPIWE	
	Area #	Yield	Area	Farms	Area	Value z
1988	5,011	38.8				
1990	5,581	43.0				
1991	7,155	67.5				
1992	8,030	89.8				
1993	6,026	66.9			5,800	\$10M
1994	6,735	66.0				
1995	8,139	55.6				
1996	8,360	69.0				
1997	9,520	64.1				
1998	11,491	90.2				
1999	13,533	97.5			15,000	\$30M
2000	20,645	152.2			22,000	\$55M
2001	19,294	140.4			22,000	\$60M
2002	19,566	291.0			20,000	\$75M
2003	17,448	194.6			17,500	\$65M
2004	12,222	140	13,284	884		
2005	11,232	172	12,929	798		
2006	8,254	150	9,601			
2007 *	7,920	123				

Tasmanian poppy production 1989 to 2007³⁶. Areas in hectares, yield in tons of morphine/thebaine equivalent. Cited year is year of harvest.

Key: # = harvested area; * = forward estimate; z = farm-gate value \$A.

ABC, 2006&2007; DPIWE, 2004; DPEM, 2006; DPPS, 2004&2005; INCB, 2002&2006; TFGA, 2006³⁷.

³⁶ Table 7.2, with its gaps and many sources of information illustrates the difficulties that the PACB and DPIWE policy of withholding statistics creates for external analysis of the industry. It is also problematic because it enables vagueness to displace specificity, ultimately allowing accountability to be compromised. In June 2007, the regularly updated PACB web page claimed that there were “on average, 1000 growers cultivating about 13,000 hectares of poppies annually in Tasmania” (PACB, 2007b), but the average area sown in the years 2004 to 2007 was under 10,000 ha and grower numbers could hardly have exceeded the 798 of 2005. At the time of writing, in June 2007, when the quoted PACB figures were listed as current and the ground was being prepared for the 2007-2008 crop, a total crop area equivalent to the cited average of 13,000 ha had not been sown since four years previously, in the spring of 2003. Moreover, grower numbers had also remained significantly below 1000 since that season when they fell to 884 (DPIWE, 2004; DPPS, 2004: 44).

³⁷ In June 2006, the TFGA (Tasmanian Farmers and Graziers Association) wrote that “the area of poppies to be grown this coming season is around 7,000 hectares, compared to 20,000

In a 26 page, June 2007 TDED (Tasmanian Department of Economic Development) promotional brochure, entitled *Biovision Tasmania 2007-2015: Tasmania's Biotechnology Strategy*, (which has a forward written by the Premier of Tasmania) a 1 page summary of the industry, headed "Case Study 01: Tasmanian Poppy Industry" states:

hectares harvested in 2002" (TFGA, 2006: 7). At the same time, the GRDC (grains Research and Development Corporation) reported that GlaxoSmithKline had cut its contracts, which had been 6000 ha in 2005, by 90% for the 2006-2007 season (ABC, 2005; ABC, 2006; GRDC, 2006).

In August 2006, the ABC reported that "at the last minute" for farmers planting spring crops, GlaxoSmithKline was offering growers contracts for a further 2000 ha on the strength of a recent sales agreement (ABC, 2006b). Later the same day it quoted the president of the Tasmanian Poppy Growers Association (TPGA) as saying the offer had come too late (ABC, 2006c). In the same month, the *Poppy Growers' Bulletin* circulated by Tasmanian Alkaloids announced that since it had "phased in" a reduction of its stockpile and contracted growing area in the previous two seasons, it would be able to increase its cropping area from 4000 ha to 7000 ha for the 2006-2007 season (Tasmanian Alkaloids, 2006: 5). In March 2007, the ABC reported that poppy plantings were likely to "double ... to 17,500 ha in the 2007-2008 season, indicating that the 2006-2007 crop was approximately 8,500 ha (ABC, 2007).

For the more dedicated, the Annual Reports of the Department of Police and Public Safety cite crop area figures, which can be considered reliable, for the previous three years. The 2003-2004 report records that in that year, the police were responsible for the security of a poppy crop covering 13,284 ha, which was grown by a total of 884 farmers (DPPS, 2004: 44). The same source reports that in 2004-2005, 798 growers cultivated 12,929 ha (DPPS, 2005: 51) and in 2005-2006, the renamed DPEM (Department of Police and Emergency Management) Annual Report recorded that the crop area had fallen to 9,601 ha. 2005-2006 grower numbers, which presumably also fell, were not included in the document (DPEM, 2006: 30).

The medicinal poppy industry has now been operating in Tasmania for over 30 years and the State is the world's largest producer of opium alkaloids for the pharmaceutical market, with 1150 growers producing 50 per cent of the world's legal poppy crop from an area of around 17,000 hectares sown to poppies (DPIW, 2006)³⁸. (TDEDb, 2007: 13).

The publication appears to have been designed to advance the notion that Tasmania aspires to be a biotechnological frontrunner and that its government is working to ensure that this dream comes to fruition. It promotes the growth of biotechnology in Tasmania as a far broader science than GM alone but singles out GM and the poppy industry for particular mention, reminding readers that the current moratorium on GM crops expires in the near future:

Tasmania has a moratorium on genetically modified (GM) crops until 2009. Whether Tasmania develops GM crops after this time is an important issue for the Tasmanian biotechnology industry given that Tasmania has several significant opportunities for economic growth in the non-food sector. One such opportunity is poppy growing for medicines. Our challenge is to investigate the issue of GM crops for Tasmania and provide certainty to industry and the community regarding Tasmania's GM status after 2009. (TDEDb, 2007: 21).

It is self evident that the provision of certainty is critical to business planning and the health of the State's economy, but as the following example demonstrates, after ten years of debate, the Tasmanian Government's biotechnology policy is still ambiguous.

³⁸ The cited reference ("DPIW 2006"), does not appear among the 12 listed references of the publication.

An 18 page, 2006 DPIW publication, with a foreward by the Minister for Primary Industry, *The State of Growth: A better approach to developing Tasmania's primary industries* subtitled *Annual Report*³⁹ April 2005-March 2006, contains an entry entitled, "Genetically Modified Organisms", which appears under the heading "Priority Strategy 4 – Building on our Island Advantage". It reads:

Tasmania has had a moratorium on the commercial release of genetically modified crops since 2000. The reason for this moratorium is to enhance Tasmania's marketing opportunities by underpinning our "clean green" image. The State was declared a Genetically Modified Organism (GMO) Free Area in November 2005. New import requirements for GMO testing of canola seed were introduced through amendment of the Plant Quarantine Manual. (DPIW, 2006: 7).

Whatever purpose or lack of purpose might be speculated to lie behind the dissemination of these incompatible and confusing policy messages, it is hard to see how the short and long-term consequences for the poppy industry could be anything other than severely negative.

The Alkaloid Pathway

³⁹ It is unclear to the casual reader whose annual report it is.

“Morphinan alkaloids”⁴⁰ occur in laticiferous⁴¹ cells that exist “predominately in aerial organs of oilseed poppy plants, such as the capsule, stem and leaf tissue” (OGTR, 2002d: 29). At plant maturity⁴² the desiccated poppy heads, or capsules, are mechanically harvested, along with the top few centimetres of stem (DPIWE, 2004: 1). The capsules are then threshed to remove the seed, which is cleaned and sold for the spice trade (DPIWE, 2004: 1; Tasmanian Alkaloids, 2007). The remaining material, known as “poppy straw” is then treated with solvents to recover the alkaloid, which constitutes 40% to 80% (usually the higher end of this range in Australia) of its content (Fist, 2001: 2; Tasmanian Alkaloids, 2007).

The extract, “concentrate of poppy straw” or CPS, is a saleable narcotic raw material that both companies deal in to a greater or lesser extent, as well as further processing it themselves into APIs. Tasmanian Alkaloids conducts its entire manufacturing operation at its Westbury plant, near Launceston in Tasmania, while GlaxoSmithKline pelletises its poppy straw and ships it to Victoria where it is processed and then mostly exported as CPS (DPIWE, 2004: 3; GlaxoSmithKline, 2007; Fist, 2001: 2; Tasmanian Alkaloids, 2007).

⁴⁰ Those generated in the morphine synthetic pathway.

⁴¹ Latex-producing.

⁴² The industry standard for maturity is 12% moisture.

Tasmanian Alkaloids produces two types of CPS, morphine and thebaine, drawn from two different poppy strains. Most of its morphine CPS is refined into codeine, while its thebaine CPS is used to manufacture strong analgesics such as Oxycodone and Buprenorphine (DPIWE, 2004: 4; EIU, 2005: 114; Fist, 2001: 2). GlaxoSmithKline also produces both kinds of CPS, but without the benefit of the top1 poppy (discussed below).

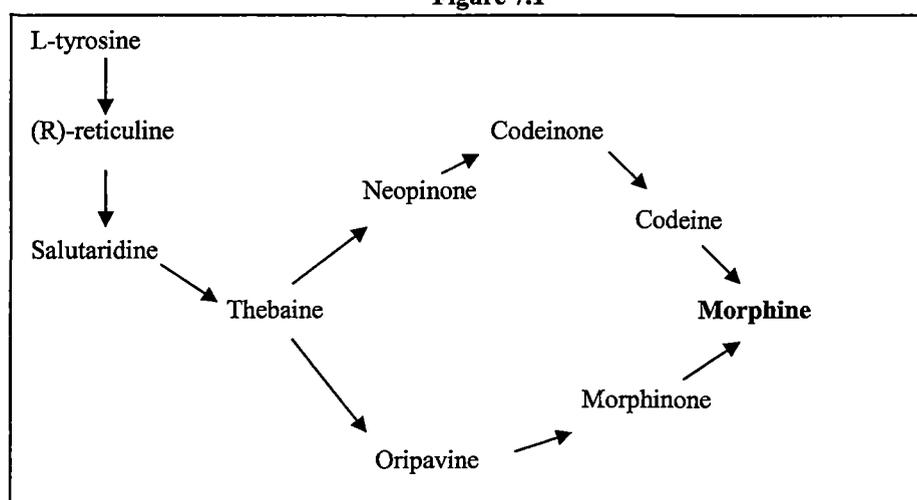
The opium poppy, *Papaver somniferum*, is the source of approximately 80 alkaloids, a number of which are of importance as pharmaceutical ingredients (Kutchan, 2005: 10). Principal among these is morphine, which is specific to this plant (DPIWE, 2004: 1). The ancient opium poppy has survived as a licit crop plant in a world economy that favours synthesised products because the pathways and enzymatic regulatory mechanisms of alkaloid biosynthesis involved are not fully understood⁴³.

⁴³ Poppy researchers Chitty et al write:

“The morphinans (5-ringbenzylisoquinoline compounds) include thebaine, codeine, morphine and derivatives. The complex chemistry of these molecules has ensured that cultivated *P. somniferum* continues to be the source of these and derived pharmaceuticals. Morphine and codeine are widely prescribed analgesics and cough-suppressing drugs ... Other alkaloids from poppy species have various uses: noscapine has antitussive and antitumorogenic properties; papaverine is a vasodilator and smooth muscle relaxant; sanguarine is antimicrobial and anti-inflammatory.” (Chitty et al, 2003: 1045).

Among the biochemical paths and products in the conventional opium poppy, morphine is the end point and final product of a biosynthetic chain, referred to as the “morphinan branch of the normal poppy pathway”⁴⁴ (Millgate et al, 2004: 413). A bifurcation in this chain (see Figure 7.1 below) provides an alternative chemical route from thebaine to morphine: thebaine to oripavine to morphinone to morphine (Millgate et al, 2004: 413).

Figure 7.1



The morphine pathway (abbreviated). After Millgate et al, 2004: 413

In addition to the main pathway involving the synthesis of morphine, there also exist side-pathways synthesising smaller quantities of other compounds. At certain points in the pathway “rate-limiting steps, or bottlenecks” appear to constrict the synthetic process (EGGT, 2001: 6). The chemistry of the

⁴⁴ Although the chemistry of morphinans is far from simple, an abbreviated sequence of the main events in the biosynthesis of morphine is as follows: L-tyrosine (stage 1), then 7 steps to (R) – reticuline (stage 2), then 6 steps (including salutaridine) to thebaine (stage 3), then 3 steps (including neopinone and codeinone) to Codeine (stage 4), then 1 step to Morphine (stage 5) (Fist, 2001: 8; Millgate et al 2004: 413).

morphinan pathway and its products have some critical implications for the future of poppy breeding and the health of the industry as is explained below.

Tasmanian Opiate Production, Markets and the Thebaine Poppy

The main intention of the 1961 Single Convention was to bring the world opium market under the control of one body in order to prevent opiate abuse. By maintaining a balance between demand and supply, the INCB aims (with mixed success) to minimise diversion of licit opium into the illicit market. Even so, illicit opium production remains a massive problem, especially in Afghanistan, which was calculated to be responsible for the production of 87% of all illicit opium in both 2004 and 2005 (UNODC, 2005: 1). For the year 2005, the INCB reported a total legal crop of 457 tons and the UNODC a total illicit crop of 4,712 tonnes or 4637 tons (INCB, 2006: 94-95; UNODC, 2005: 1).

Turkey began poppy straw production under the terms of the Single Convention after the US failed to persuade it (as the principal source of illicit heroin entering the US) to ban poppies in the late 1960s. The UN provided technical assistance and other resources and as a precautionary measure also asked pharmaceutical manufacturing nations to preferentially source their

raw opiate from Indian and Turkish opium gum stocks (Kamminga, 2006: 5-9).

In accordance with policy dating from 1942, the US forgoes domestic poppy production and relies on imports. It also prohibits the import of finished narcotic products and requires that its importers have the capacity to process both gum and poppy straw (Indian Ministry of Finance, 2007). In 1981, it “gave legislative effect” to the UN request (see Title 21, part 1312.13 (g) of the Code of Federal Regulations), “extending a “special protected market status” to Turkey (and India) under a Drug Enforcement Agency Regulation, commonly known as the “80-20” Rule” (Kamminga, 2006: 9). This rule obliges US importers to purchase at least 80% of their narcotic raw material from Turkey and India⁴⁵. At that time this ratio reflected the existing ratio of production between traditional and new producers. India and Turkey may also compete for the remaining 20% of the US market against five other producers – Australia, Yugoslavia, France, Poland and Hungary (DPIWE, 2004: 2; Indian Ministry of Finance, 2007).

The ban on imports of finished narcotic products further constrains Australian access to the US market, preventing sales of “APIs such as

⁴⁵ US trade consequently includes large quantities of opium gum, even though the regulations that entrench this arrangement are probably in breach of WTO principles. While market forces are obviously distorted, the threat that free trade might bring to existing international control of at least some of the opiate market appears to have greater priority.

codeine phosphate” (Fist, 2001: 2), which significantly limits the commercial freedom of US drug companies (Indian Ministry of Finance, 2007)). In 1998 the US imported 541 tonnes of opium gum (which contains about 15% API) and 38 tonnes of CPS (40% to 80% alkaloid) while the only larger importer of CPS, the UK, purchased 49 tonnes (Fist, 2001: 3; INCB, 2006: 72).

However, the much higher alkaloid content of CPS means that 80:20 can be a somewhat misleading term. The fact that Tasmania has on occasion been able to approach satisfying the majority of world demand is suggestive of a more level playing field than the term implies. Even so, its impact in Tasmania is not even-handed. GlaxoSmithKline is British based and has always focussed on supplying markets in the UK and Europe, whereas the American owned Tasmanian Alkaloids is primarily oriented towards the US market, so it is affected more severely by the 80:20 rule (Chemlink, 2007). Tony Fist, who heads poppy research for Tasmanian Alkaloids, also points out that Australia faces some other disadvantages: “France has a large, protected local market for codeine. The industries in Turkey and India are run by the governments as rural assistance programs, and these countries have much lower wages than Australia” (Fist, 2001: 2).

The local industry’s most important innovation to date arose in the early 1990s from Tasmanian Alkaloids’ identification of a potential for growth in the thebaine market, associated with the development of strong, morphine-

alternative analgesics such as Oxycodone and Buprenorphine”, which can be manufactured from it⁴⁶ (Tasmanian Alkaloids, 2004). Over the period 1994 to 1997, the company’s research team⁴⁷ developed a new, thebaine-accumulating poppy, the “top 1”⁴⁸ variant, which has become commonly known as the “Norman” Poppy⁴⁹.

⁴⁶ Thebaine itself is a dangerous convulsive, with no useful medical properties and occurs before morphine in the biosynthetic pathway (Dicker, 2001; Fist, 2001: 7). It can be converted into various compounds including codeine, hydrocodone, hydromorphone, oxycodone, oxymorphone, nalbuphine, nalaxone, naltrexone, buprenorphine and etorphine (Graas, 2007). It was previously used to a limited extent in the synthesis of strong analgesics and anti-addiction therapeutics, but its supply was limited as it normally occurs in poppies at low levels and although chemically recoverable from morphine, it is a technically difficult process CPS (Dicker, 2001; Fist, 2001: 7)

⁴⁷ The project, led by Dr Fist, involved an elegant breeding and scanning program in which seeds were subjected to chemical mutagenesis and the resultant seedlings screened, using a new high-volume, non-destructive analytical technique capable of evaluating 1000 plants a week (Fist, 2001: 8). The undertaking, which began in 1994, was immensely successful in producing a new variety and “must have set a land speed record for commercialisation”, according to CSIRO poppy researcher, Dr Phil Larkin (Milius, 2004). Within three years of the project’s establishment, that is by the 1997-1998 season, a 500 ha commercial crop of the new poppy had been sown (Fist, 2001: 8). The Norman poppy has since become Tasmanian Alkaloids’ predominantly planted poppy type (Fist, 2001: 8) and 2006 INCB projections suggest that Tasmanian thebaine production will outstrip its morphine production from 2007 (INCB, 2006: 94-95).

⁴⁸ In the *top1* poppy, the bifurcated morphinan pathway is genetically blocked at thebaine and oripavine (Fist, 2001: 7-8; Millgate et al, 2004: 413), so the laticiferous cells accumulate these two alkaloids, rather than morphine (see Figure 4.1). Oripavine, which is chemically similar to codeine, but more useful as a chemical precursor, is produced in quite large quantities in *top1* but can be easily methylated to produce thebaine (Dicker, 2001; Fist, 2001: 8). Thebaine can also be used for codeine production, but neither thebaine nor oripavine can be readily converted to morphine or heroin, which steeply reduces the “risk of diversion for illicit purposes” (Fist, 2001: 9).

Tasmanian Alkaloids has consequently been producing buprenorphine, oxycodone, naxalone and naltrexone since 1998, as well as exporting thebaine/ioripavine CPS. The major markets are, unsurprisingly, in the US and Europe (Fist, 2001: 2) and “top 1” now accounts for the majority of this company’s contracted acreage⁵⁰. The change to the nature of the market means that the US’s 80:20 rule has, temporarily at least, been circumvented (DPIWE, 2004: 3; Fist, 2001: 8).

According to the TPGA (Tasmanian Poppy Growers Association), the dynamics of the alkaloid market are such that expansion, diversification and periodic shifts of demand are occurring⁵¹. As the requirement for morphine

⁴⁹ Allegedly a grower corruption of “no morphine”.

⁵⁰ Although several alternative approaches to blocking the morphinan pathway at thebaine were considered, including genetic modification, conventional plant breeding techniques were ultimately chosen. How a successful GM project might have influenced State GM policy is open to speculation, but Fist considers that the choice of mutagenesis, which is uncontroversial, was fortuitous in the light of this (Fist, 2001: 8).

⁵¹ Both companies are exploring new areas of operation and are offering growers contracts for new varieties bred in response to gaps at the supply end of the industry. Tasmanian Alkaloids has been reported to be beginning commercial oilseed production and in the 2006-2007 season contracted about a fifth of its crop for a new poppy with enhanced noscapine accumulation. Noscapine is a non-narcotic alkaloid that is used as a cough suppressant (ABC, 2006d; Grant, 2007b). GlaxoSmith Kline, which in addition to its morphine enterprises, already contracts farmers to grow a conventional poppy variety with enhanced

has waned, first thebaine and then oripavine have been increasingly sought by pharmaceutical manufacturers. The TPGA's Chief Executive, Keith Rice, has suggested that the changes in the market could result in Tasmanian Alkaloids becoming a specialist thebaine/oripavine producer in the near future (Grant, 2007b).

GM Poppies in the Tasmanian Context

Tony Fist (2001: 5) has identified the two basic economic requirements of the pharmaceutical opiate industry as "a high alkaloid percentage in the straw, and a high alkaloid yield per hectare". Both of these demands reflect the pressure that is applied by consumers to producers via the market, to maximise cost to return ratios.

The first requirement is primarily related to the efficiency of the processing stage, which directly increases with the rate of extractable alkaloid per unit of straw (Fist, 2001: 5) and has a direct bearing on the competitiveness of the industry as a whole. The second relates to the growing stage and is pertinent to the issue of the continuing availability of sufficient, suitable land in Tasmania, as well as that of crop viability⁵² (Fist, 2001: 5).

thebaine content, is also reported to be making contracts with growers for noscapine poppy crops (Grant, 2007b).

⁵² The matter of crop viability is common to all free market agricultural systems. Farmers normally choose to produce the most profitable crop or stock that their conditions allow. The Tasmanian alkaloid companies, therefore, whose ability to purchase raw material is limited

The ongoing availability of poppy-growing land is not an immediate concern, but is a potential limitation to expansion of the industry, which could conceivably threaten it economically by creating opportunities for competitors⁵³. Sustainable level of land use is considered to have approached the point of saturation in the peak years around the turn of the century (Chitty et al, 2003: 1045). Without technological advancement the industry can only grow by making agronomic compromises that are likely to lead to economic disadvantage⁵⁴.

by the value of the alkaloid they can recover from it, are also dependent upon crop yields being sufficient to provide growers with an acceptable return per hectare of crop.

⁵³ While the maximum area planted to date (22,000 ha) is only a fraction of the State's viable agricultural land, the range of suitable sites is severely restricted by peculiar agronomic limitations such as soil type, topography and water availability. The important, but far less predictable factor of competition from other crops further reduces the amount of land that is available, while the persistence of soil-borne poppy pathogens necessitates the maintenance of three to four year crop rotations for effective disease control (Chitty et al, 2003: 1045; Fist, 2001: 11). The need for rotation translates into an overall requirement of 3-4 times the annual planted area, which at the 22,000-hectare level is 66,000 to 88,000 hectares.

⁵⁴ If it accepted that competitive markets continuously drive producers towards greater efficiency and productivity, innovative technology that facilitates production, is bound to eventually become economically imperative. Over time the *possible* becomes the *standard*. Before the mechanisation of everyday agriculture with such revolutionary introductions as practical tractors and milking machines in the years following World War I, humans and horses contributed almost all farm energy inputs. As always, innovative, prosperous and ambitious farmers first adopted the new technologies and demonstrated their economic advantages to the rest of their communities. Now, of course, mechanised agriculture sets a minimum standard of productivity, below which it is not possible to function economically.

Tony Fist has observed that the traditional opium producers competing for market share with Australia are advantaged by the low cost of their inputs and the preferential treatment that the US affords them (Fist, 2001: 2). Given these limitations, the Tasmanian industry, with its high cost structure, could not participate in the marketplace without the sizeable technological lead that it has accrued and which it has to maintain. In a competitive environment, advanced technology is inevitably vulnerable to predation by less efficient competitors who will, if they can, adopt it and reap its benefits.

It, therefore, becomes an economic necessity for the Tasmanian industry to maintain the momentum of technological advancement in terms of the products it can offer and the means by which they are produced. The Norman Poppy was born of excellent science and was no lucky accident, but the circumstances that led to its genesis were unique and the quality of the result was fortuitous. The same effort might have come to very little. Competitors will inevitably work towards cutting back Tasmania's technological lead. The basic research requirement of the industry is not complicated: "The major challenge ... is to continue to improve its production efficiency, through

In the same fashion, dairy farmers each now milk herds numbering cows by the hundred, rather than a couple of dozen, fruitgrowers singlehandedly manage farms that would once have supported many families and grain is only profitable when grown in hundreds or thousands, rather than tens, of hectares.

improved cultural practices and increased alkaloid content of the varieties grown”⁵⁵ (DPIWE, 2004: 6).

⁵⁵ As part of its initial response to the anti GM campaign, in 2000, the Tasmanian Government established the Experts Group on Gene Technology, (EGGT), to investigate “the issues raised by the application of Gene technology to opium poppies in Tasmania’s primary industries” (EGGT, 2001: title page). In its 2001 report, this small but diverse group of specialists accepted that GM poppy research elsewhere in the world posed a very real threat to the Tasmanian industry. It pointed out that “active research [is] known to be occurring in “Canada, USA, Turkey and possibly also in France” (EGGT, 2001: 5).

The report confirmed that “the primary aim of genetically modifying poppies is to alter the alkaloid content or alkaloid profile of the crop” (EGGT, 2001: 6) and explained the vulnerability of the Tasmanian industry’s position:

“the alkaloid companies in Tasmania consider that increased productivity of alkaloids through gene technology is a realistic opportunity that has the potential to increase the competitiveness of the industry. It has the potential to create opportunities through increased production of specific alkaloids in the plant that are currently only present in very small quantities. Should the industry be excluded from such technology it is possible that the market share currently enjoyed by Tasmania may be eroded.” (EGGT, 2001:5).

It also outlined the particular kinds of biochemical mechanisms likely to be useful and accessible to gene technology and indicated that the nature of industry’s needs were such that GM would most likely involve only genes from within the *Papaver somniferum* species or other types of poppy:

“It is theoretically possible ... to increase production of particular alkaloids in the pathway by modifying rate-limiting steps or restricting alternate branches and/or steps in the pathway . . . It is most likely that initial work will involve repeating genes already present in the poppy plant, or in other poppy species, or using antisense DNA (genes in reverse order) to prevent expression of alkaloid genes in the plant.” (EGGT, 2001:5)

Stephen King commented that he spent 45 years of his life moving the decimal point in the alkaloid content of poppies one place to the right, from 0.2% to 2% of dry matter (Rogers, 2004: 14). Tony Fist estimates that alkaloid yield increased threefold during the first quarter century or so of alkaloid production in Tasmania (Fist 2001: 5). This increase was the product of diverse varietal, cultural and technological improvements, and ongoing research and innovation ensures that yields from poppy farming continue to slowly rise⁵⁶ (DPIWE, 2004:2; Fist 2001:1-13).

Comparative performance with competitors cannot be established from INCB harvest and sales figures due to the controlled rundown of excessive stocks that has been occurring worldwide over a number of years. Figures from the 1990s reported by Fist in 2001 show that Australia averaged 9.3 kg/ha, France 7.0 kg/ha, Spain 4.9 kg/ha and Turkey 1.1 kg/ha (Fist, 2001: 3).

Although further yield improvement may be possible, the potential to extract alkaloid from the existing varieties is limited by their genetic makeup and the big gains from conventional breeding and growing technology have, almost certainly, already been made (Chitty et al 2003: 1046). As the natural limits

⁵⁶ A 2003 Tasmanian Alkaloids publication, the Poppy Growers' Bulletin, published some informative yield statistics for the company's top ten growers for the year (Tasmanian Alkaloids, 2003: 5). It cited the top alkaloid content as a percentage of dry matter as 3.67% (average for the ten was 2.88%) and the top alkaloid content as alkaloid yield per hectare as 34.03 kg/ha (average 31.99 kg/ha). Poppy researchers, Chitty et al (2003: 1046), report that the general range of alkaloid content in the Tasmanian industry is 1.5% to 2.7%.

of the production system are approached, it becomes increasingly difficult to enhance yield. Conventional breeding is also limited in its capacity to provide varieties that accumulate alternative alkaloids, for which demand might develop and the solution to these limitations that most logically arises from the body of scientific knowledge is genetic modification⁵⁷.

A small but, for Tasmania, possibly significant development in the context of technological evolution is the re-emergence of a poppy industry in the UK. From an initial planted area of 428 hectares in 2002, it grew to 2000 hectares in 2004 but fell back to 1500 in 2005 as a consequence of the generally experienced problem of over-supply (Fowler, 2006: 77; INCB, 2006: 93).

⁵⁷ Chitty et al (2003: 1046), in the introduction to their paper describing experimental genetic transformations of Tasmanian cultivars of the opium suggest that poppy alkaloid synthesis is able to be manipulated by:

“...enhancement of the activity of enzymes at “bottlenecks” in the alkaloid synthetic pathway; blockage of undesirable “side reactions” and blockage of the synthetic pathway at specific steps so that certain desirable alkaloids accumulate.”

A number of descriptions of successful modifications of *Papaver somniferum* have been published (Chitty et al, 2003; 1045 - 1058; EGGT, 2001; 5; Park and Facchini, 2000: 1005) although details frequently are not released, for reasons of commercial sensitivity.

Chapter 8.

ANALYSIS

Developing a Framework of Analysis

Comparative study demands that the two policy approaches under scrutiny be gauged according to a constant value or series of values. Since the descriptive form used in the research question (“better”) is too vague to apply as a measurable constant, its significant components need to be established.

However, discriminatory decisions about what would constitute better GM regulation have to be made, which is a process inviting bias. The determination of analytical criteria is, therefore, a potential area of investigative weakness that must be accepted as a natural limitation of the objectivity of the research process. Another source of possible bias is the reductionist nature of analysis. It is not possible to bring order to disordered information without creating classes defined by significant qualities. This brings simplicity to complexity and allows comparisons to be made, but also risks the exclusion of some information from consideration. Final results could be inadvertently skewed by this means.

The reform of chemical spray programs in GM cotton production, for example, has had consequences of economic, environmental, social, political and scientific import, so considering it as an economic issue alone might exclude critical agronomic or environmental data. However, providing the

analytical framework is broad enough to encompass all the relevant considerations and as long as the complexity of the factors that are being weighed is recognised, there is no reason for information of significance to be lost.

The list of contentious issues surrounding GM crop debate is effectively infinite as long as science progresses and debate continues, so it can never be exhaustively articulated. The position of its proponents is centred on the advantages offered by GM technology while the position of opponents to its adoption is chiefly focussed on the risks. Both sides rest their arguments on moral premises that have strong relevance and support within the Australian community.

The specific claims can be analytically grouped in various ways without introducing pronounced bias, as has been the case in various government investigations of GM. The range of concerns from all viewpoints is easily illustrated by means of reference to these. The House of Representatives committee report *Genetic Manipulation: The Threat or the Glory* (Lee, 1992), for example, considered the issue of GM technology in four substantial categories: 1. Philosophical, ethical and social issues, 2. Environmental questions, 3. Human health concerns, and 4. Legal matters. In contrast, the Tasmanian Parliamentary committee's *Report on Gene Technology* (JSCGT, 2001) used four somewhat different categories,

reflecting the logic of slightly different needs and priorities. These were: 1. environmental questions, 2. social and ethical issues, 3. economic costs and benefits, and 4. marketing concerns. Neither structure necessarily precludes full and objective coverage of the topic, nor has there been any public suggestion of bias or inadequacy in this respect.

Rationale and Criteria

Because this study is concentrated on the pragmatic significance of regulatory outcomes, input considerations such as ethical and philosophical questions are not considered. It is assumed that legislators will have resolved these matters prior to the establishment of a regulatory regime for GM varieties and that there are no generic obstacles to the development and use of GM technology in Australia.

Legal factors and implications are also not considered on the grounds of their limited relevance to the research question and the specialised nature of the subject. Aside from describing the major difficulties provoked by the existing legislation, problems of a legal nature are regarded as the domain of legal experts.

The choice of criteria for this analysis follows the logic that any regulatory action results in particular events that in turn have various social effects. Unless links are emphasised, the ultimate significance of direct and mostly

physically measurable outcomes, such as variations in chemical applications or the type of chemical applied may be overlooked. Important consequences to individuals, families, institutions, social groups and communities may exist and be felt through the entire community. The regulation of GM crops may also have significant impacts that become apparent over time. Accordingly, the criteria selected are arranged in four groupings of impacts that can be understood to adhere to a pattern of increasing distance from the causal event.

The primary or “Direct-Physical” category includes the obvious, direct consequences of a regulatory decision. These primarily affect growers using the product and the physical environment, effectively constituting the realms of agricultural science and environmental science. Changes to the yield and quality of produce, data relating to agricultural practices and chemical usage, changes to soil and water and the broader natural environment, and changes to physical human environments are considered.

The second category (“Economic-Material”) includes consequences relating to the human material condition, or economics. These are usually less directly measurable but closely dependent outcomes. The most, obvious and important is the profitability of the crop to both the grower and the industrial sectors that use it or its byproducts.

The third category (“Conceptual-Research”) is comprised of the longer-term ramifications of economic consequences and is considered as a gauge of how the regulatory process has affected perception of the crop and its economic potential. The state of crop research and technology, and changes of direction are the variables examined.

Table 8.1

GM CROP	REGULATORY INFLUENCES			
	Direct (Physical)	Economic (Material)	Conceptual (Research)	Social (Political)
Cotton				
Canola				
Carnation				
Poppy				

Schematic presentation of the analytical framework.

The last category (“Social-Political”) provides the opportunity to include broader social consequences of the regulatory activity. The most conspicuous of these is the state of resolution of controversy in the community, or the political status of the crops.

Table 8.1 graphically represents the framework of analysis that will be applied. An analysis of GM crop regulation in Australia, conducted along

these lines will be set down in the following order: cotton, canola, carnation, poppy.

The quantity of available material for analysis varies among the cases. Cotton and canola are plentiful sources, partly because they are both major crops that have attracted a good deal of attention. Cotton has a long history of both GM and non GM production resulting from the entirely science-based regulation of the 1990s. In the case of canola the science-based Canadian example provides a valuable contrast with the Australian industry. The Australian GM carnation has been grown for a long time, but is the product of a tiny industry that avoids unmanaged publicity. Information is difficult to access. Poppies are confined to Tasmania but since that State now has a hardline GM-free policy, no GM poppies are grown or currently being developed. As no GM poppies are yet in commercial production anywhere else, comparative opportunities are limited.

Regulation of GM canola by the Australian States is necessarily treated as if it was uniformly precautionary. Although the regulatory arrangements have changed in the States of Victoria and NSW in November 2007, there is as yet have no Australian history of science-based regulation of canola production to draw upon. Queensland has never applied precautionary regulation to GM crops, but it has no canola industry.

Genetically Modified Cotton¹

The direct consequences of scientifically based regulation of GM cotton².

The commercial use of GM cotton means that large numbers of GM plants are released as seeds into the environment where they are to be grown. This environment may for analytical purposes be considered to consist of three sub-environments: firstly, the soil and its inhabitant life; secondly, the water environment, including soil moisture and all downstream aquatic environments; thirdly, the open-air environment and its inhabitant life including humans. This analytical concept will also be retained for the three other GM cases being considered.

Influences on the soil.

The two possible avenues for GM cotton impact on the soil environment are (a) the presence of additional Bt genes and their products in the rhizosphere (root zone) and (b) the reduction in chemical applications.

¹ This analysis is concerned with GM Bt cotton and the term “GM cotton” may be applied to refer to this varietal form. Herbicide resistance is of far less importance for this crop and is specifically dealt with in discussion of GM canola.

² Perhaps the first, major consequence of this form of regulatory decision is that commercial GM cotton crops have been grown in Australia. Equally importantly, other GM crops have not survived the journey from conception to commercial reality. The CSIRO’s blue pea has already been cited as an example of a potentially unsafe GM crop that was rejected by the scientific process. However, since science is in practice self-regulating (through orthodoxy, transparency and peer review) it is not possible to quantify the number of cases of unacceptable GM risks that have been eliminated through routine procedure. This function of science can be regarded as a parallel to the protective intent of precautionary regulation.

(a) With respect to the first possibility, Bruce Finney, Executive Director of the Cotton Research and Development Corporation (CRDC) commented in a 2006 interview for this study: “I am aware of investigations that have shown that there are observable differences in soil microbe populations, but they do not pose any kind of threat” (Finney, 2006). This understanding reflects the consensus of research results. Dr Diana Walter’s recent PhD research, which was jointly organised and funded by the Department of Medical Biotechnology at Flinders University and CSIRO Land and Water, investigated the microbiological impact of Bt cotton in soil. It concluded that observable soil differences between cotton plants correlated more closely with varietal differences than with GM status. The main research “compared the rhizosphere microbiota of four *Ingard* cotton plant varieties that were closely matched with their non-GM parental strains” in three different soils:

The outcome of this work was the acquisition of scientific data to produce an environmental impact report ... The results ... did not show that there were consistent effects on the rhizosphere soil microbiota that could be attributed to the presence of the Cry1A(c) Bt plant protein on the selected strains of cotton plants. The results from the tests of paired trials correlate highly with previously published work [which reported that] that the risk factors of genetically modified cotton on the microbiology of the rhizosphere soil were found to be negligible. (Walter, 2005:1).

As a study of apparently impeccable scientific credentials, the confirmation of earlier findings provides a sound basis for the conclusion that GM Bt cotton has no significant adverse effects on the soil environment. The paired

trials show that the outcome for microbiota in the rhizosphere would not be markedly different if precautionary regulation were to suspend the use of GM cotton.

(b) The possibility that reduced insecticide applications might have undesirable soil impacts is hypothetically feasible, but the likelihood is so slight it does not warrant consideration here. It is rather assumed (in line with broadly accepted understandings) that the soil environment has benefitted from the change. Steep reductions in the levels of chemicals such as endosulfan and pyrethroids in the soil must eventually lead to significant decreases in detectable residues in the crop itself, in soil water, and in other environments and organisms. Falling residues benefit the human food chain and indigenous life-forms, which have been affected by residues in the past.

Such residue reductions could not have occurred had a precautionary approach to GM regulation existed State level in the 1990s. The use of Bt cotton would almost certainly have been disallowed on the basis of biosafety risks and a putative threat to export markets³.

³ As with GM canola, even though the science was clear, the existence of even minuscule doubts would have demanded a ban. It seems likely that this would ultimately have led either to closure of the Australian cotton industry or enforced perpetuation and tolerance of the chemical pest control approach of the early 1990s, along with its many disadvantages. The profound problems associated with the persistence and movement of chemical contaminants in the environment and the industry's need for effective *Helicoverpa* control were the main drivers of the development of Bt cotton technology. Both of these issues have been almost completely disposed of since its introduction, but would presumably re-emerge

Influences on environmental water⁴.

As with the soil environment, there are two main avenues for GM cotton to impact on water. Again these are (a) the presence of additional Bt genes and their products and (b) the sharp reduction in chemical residues.

(a) Since research, such as that cited in the previous section, has shown that the soil environment is not significantly affected by the presence of GM cotton, it is reasonable to assume that the water flowing over and through it is similarly unaffected. Consequently, in the wider, diluted environment, water would not be expected to exhibit signs of quality diminution and there appears to be no suggestion in the scientific literature that Bt cotton has significantly compromised the quality of the water environment.

(b) The potential for undesirable chemicals used on conventional cotton crops to be detected in downstream water and in food products such as meat has

if Bt cotton were now to be banned on the basis of concern with GM technology. On average, 5.5 kg/ha or a total of 6,200 tonnes *less* chemical concentrate is now applied to Australian cotton crops each year (Roush, 2004, 4).

⁴ For the sake of this analysis, the water environment is considered to consist of the soil water that exists where a cotton crop is grown and all water downstream of it in the water cycle. As a ubiquitous, essential and highly mobile physical component of natural systems, water is intimately associated with the transport of various materials and organisms within the wider environment. While life itself depends upon its many functions, the dissemination of environmentally destructive materials and entities is also largely dependent upon the nature and movement of water. There is consequently a potential for residues of both GM crops and agrichemicals to be transported throughout the environment by water.

been well investigated. The example of the association between fish kills and endosulfan contamination of waterways (LWA, 2005:94) has been cited in the cotton case study (Chapter 4). A report prepared by water resources analyst, Peter Crabb, for Environment Australia in 1996 (the year that GM cotton was first introduced) made the observation that:

Most farms have closed reticulation systems to retain unused water within their boundaries. However, some runoff is inevitable and studies have indicated the presence of some chemicals, such as endosulphan and atrazine, in the river at levels above those considered safe for aquatic ecosystems. (Crabb, 1996: 79).

Contamination of meat with endosulfan residues has been a serious issue with impacts that were still being felt in overseas trade after GM varieties had begun to significantly reduce use of the chemical.

In the late 1990s spray drift from cotton crops and feeding of cotton trash to cattle resulted in endosulphan contamination of beef herds. The outcome was some disruption in some export markets. (Dixon, Vassallo and Diment, 2005:2).

In 2004 Cotton Australia reported that endosulfan had not been detected in beef “for over two years” and that “monitoring in rivers has indicated significant reductions in endosulfan loads”⁵ (Cotton Australia, 2004).

The association of Bt cotton with a vast improvement in water quality is

⁵ Beef contamination was linked to illegal use of cotton plant waste as cattle fodder and excessive endosulfan residues in aquatic environments. It is, however, clear from patterns of reduction that the major factor in chemical residues reduction was the removal of general reliance upon chemical caterpillar control through the use of Bt cotton.

taken for granted in the cotton-growing regions. In response to a question concerning community reaction to GM cotton, the CRDC's Bruce Finney said:

There is less spray drift, less aeroplane activity, the water is cleaner and problems such as odour and fish kills are a thing of the past. There used to be a lot of complaints and environmental difficulties such as high endosulfan levels in the rivers. The headline issues have gone in respect of pesticides. (Finney, 2006).

Adam Kay⁶, General Manager, Cotton Seed Distributors (CSD), Wee Waa, NSW, concurred:

Before it [GM cotton] became available there were constant problems with pesticide drift and smells and contamination of soil and water. Aeroplane activity was continuous through the growing season and was regarded as a public nuisance by a lot of people. These are now a thing of the past. (Kay, 2006).

Precautionary bans on GM cotton and a return to conventional varieties would inevitably result in a resurgence of environmental water contamination and threats to wildlife, food and trade.

Influences on the open (air) environment

The two possibilities for environmental impacts are (a) the presence of additional Bt genes and their products and (b) the reduction in chemical residues.

⁶ Subsequently appointed CEO, Cotton Australia.

(a) The potential for Bt genes to affect the open environment can be considered as either of two possibilities - direct chemical/biochemical impacts or genetic impacts. These questions have been comprehensively addressed as a matter of course by the developmental and regulatory processes of GM technology and have been discussed to some extent in the cotton case study. In the case of the first possibility, impact beyond that on the target pests is minimal. Scientific affirmation of the specificity of the Cry1Ac and Cry2Ab proteins and the restriction of damaging exposure to them to vulnerable parasites of cotton that consume GM plant material has been confirmed by the GM Bt experience.

The presence in the open environment of the soil bacteria *Bacillus thuringiensis* (Bt) and its components and products is not a change triggered by the introduction of GM Bt crops such as cotton⁷. Bt is a ubiquitous microorganism, which was originally isolated and identified over a century ago in Japan, as a cause of disease in silkworms that arises from its frequent presence on mulberry leaves (Dingle et al, 2005: 21). CSIRO cotton breeder, Peter Reid, who was interviewed in 2006 described Bt as “a naturally occurring and commonplace bacteria” (Reid, 2006).

⁷ Bt sprays have been employed as a caterpillar-specific crop spray for over half a century (Dingle et al, 2005: 50). The CRDC’s Bruce Finney pointed out, “Bt is benign. It is the preferred insecticide of organic farmers and has been for years. It can be applied to fruit and vegetables up to the day before harvest” (Finney, 2006).

Exposure to Bt through food is general in the community and its safe consumption by humans, even in relatively large amounts seems well established. Similarly, consumption of Bt by animals other than susceptible insects (such as silkworms) over this time has not presented any problems. The use of GM cottonseed hulls as stock feed is not uncommon and has not been found harmful over its now quite long period of use⁸.

CSIRO cotton breeders monitoring the impact of Bt cotton have found no evidence of damage to benign and predator insects populations as the following brief extract, repeated from the case study points out.

Large ecological impact studies failed to find any significant effect on the several hundred insect species found in cotton fields, other than the expected reduction in the numbers of the very few insect species that exclusively predate on or parasitise *Helicoverpa*, since the number of caterpillars, their food source in the Ingard crop, was significantly reduced. (Constable, Llewellyn and Reid, 1998).

⁸ The hulls of cottonseed are used as stockfeed. The digestive systems of cattle that have been gradually introduced to cottonseed hulls are capable of detoxifying them, so this material can safely be used as feed as long as the quantity in the diet is not excessive (OGTR, 2002: 18). Cottonseed hulls have consequently found a reliable market as a protein supplement for stock (Cotton Australia, 2006: 3) and Australia annually exports some \$50 million worth of cottonseed to the US, Saudi Arabia, Japan, Korea and Taiwan (Cotton Australia, 2006: 13). In cases where “inactivation or removal” of the toxins during processing has taken place, the material may also be used as feed for “catfish, poultry and swine” (OGTR, 2002: 18). The poisonous nature of cottonseed in its natural state is apparently no more of a threat to wildlife than any other naturally occurring toxin. According to the OGTR, birds find the fibrous seeds unattractive, while mammals tend to avoid them due to “both the gossypol content and the morphology of the plant” (OGTR, 2002: 18).

With respect to bee and honey exposure to Bt cotton, Bruce Finney of the CRDC said:

Honey is grown in the region, but apiarists have not raised GM cotton as a problem. They occasionally have problems with spray incidents because a lot of pesticides are toxic and they can lose bees. There was a spray incident last year, but the reduced pesticide use means there is far less potential for their occurrence. (Finney, 2006).

Cotton Breeder, Peter Reid agreed:

Bees are not particularly attracted to cotton. They are more inclined to target things like sunflowers or natives. Apiarists would have traditionally avoided cotton anyway because of the pesticide risk. This has never been raised as a concern. There are apiarists operating in the area, but not operating near cotton fields in the summer. (Reid, 2006).

Consideration of the second possibility regarding Bt in the open environment – that genes might flow to other organisms - is a fundamental concern of GM regulators and developers of biotechnology, and is extensively investigated prior to the issuing of an OGTR licence. In the case of GM cotton, initially strict safety measures such as the 22 degrees latitude South geographical limitation have been eased as experience has established risk levels. Many safeguards remain in force.

The OGTR publication, “The biology and ecology of cotton (*Gossypium hirsutum*) in Australia” (OGTR, 2002: 17-24) identifies and itemises specific areas of risk in respect of uncontrolled gene transfer. There has been no

serious suggestion that unwanted or unexpected gene flow from GM cotton has occurred in Australia or elsewhere.

(b) The reduced use of chemicals in Bt cotton crops means that many of the problems of the past are vastly reduced or even eliminated. Considering that the reduction in insecticide sprays is in the region of 80% to 95%, (Finney, 2006: Roush, 2004, 4) it is reasonable to assume that impacts now range from around 5% to 20% of their previous level. In terms of environmental chemical load, the reductions can be presumed to benefit all populations including humans, natural fauna and livestock.

Fewer chemical applications means less damage to non-target species and less evolutionary pressure for the development of resistance by insects, which in turn means that the chemical that is applied is more effective. Reduced spray frequency logically translates into significantly reduced energy consumption, reduced soil compaction from heavy machinery and reduced noise from aeroplanes. From the growers' perspective, smaller pest control demands represent lower management and labour costs, with further savings on outgoings such as machinery maintenance and repair.

Reduction in demands on growers' time and resources means that other aspects of crop management that limit productivity, such as nutrition and water, can receive more attention. Bruce Finney emphasised the overall

improvement of the industry:

It used to be ironically said that pests were responsible for 25% of the costs and 80% of the worry associated with cotton growing. Now they are responsible for 20% of the costs and 20% of the worry. The concerns of the grower are now focussed on other aspects of production. ... It enables them to do their job better. (Finney, 2006).

Peter Reid described the practical difficulties that growers of conventional cotton face:

A bad insect year is the driving concern in a conventional crop. ... Dryland farmers using ground rigs for spraying can frequently be up all night. These crops cover big areas and insect control can be a huge burden for them. (Reid, 2006).

This aspect of direct change will be further considered below as an economic factor. Precautionary regulation would disallow the use of GM cotton and so could not have led to these outcomes. A precautionary ban on Bt cotton would involve more wasteful operating practices and a greater chemical load on the environment.

The economic consequences of scientifically based regulation of GM cotton.

“Economic” consequences of regulation are defined, for the purpose of this analysis, as effects that pertain to the human material condition. Although rigorous logic and science would demand that the points made in the previous section be methodically followed through to their economic, cultural and social ends, constraints of time and space prevent this. Consequently, the analysis in all four cases is confined to consideration of the most strongly

defined economic impacts at three representative levels – the enterprise/grower level, the community/regional level and the broader, national level. Although alternative structural breakdowns are possible, these groupings are clearly defined, capable of being exhaustive, reflect the context and parameters of most data, and involve the same logic as the analytical framework.

Enterprise Level

The scale and rapidity of GM cotton uptake reflects the preferences of cotton farmers and indicates the scale of its material value to the industry. Australian cotton export volume more than doubled over the five years following its introduction (Turco, 2003: 38), which argues sharply increased profitability. The assumption that GM varieties were central to this expansion requires some establishment and the ways in which GM technology materially benefits grower operations need clarification.

In an interview conducted during the 2006-2007 growing season, Adam Kay, General Manager of CSD, a cottonseed supplier said that the GM portion of total seed sown had reached 93% (Kay, 2006), but this figure does not mean that 7% of farmers prefer conventional technology. As Peter Reid of the CSIRO pointed out, the total seed percentage actually translates into an even higher percentage of growers.

Given that many growers plant both conventional and GM varieties, it probably means that close to 100% of all growers utilise the technology to

some extent. This level of adoption demonstrates the need for the technology. (Reid, 2006).

Auscott Limited, a relatively large cotton farming concern, typically grows 5,000 ha of irrigated cotton annually near Narrabri, NSW. Its varietal choices each year are made in accordance with a number of constraints and although GM lines predominate, some conventional (non-GM) cultivars are grown too. Their agronomist, Tom Breen, described a number of specific agronomic benefits of GM technology, but also asserted that ultimately these must amount to a bankable advantage, “The bottom line is that the most profitable option is the most attractive” (Breen, 2006).

All interviewees from the cotton industry identified simplicity and ease of management, rather than simple cost/profit mathematics as the key to the success of Bt cotton. Peter Reid explained that...

GM is not essential for varietal performance. Conventional technology is good, but production is so much easier using biotechnology. ...Using GM varieties allows growers to concentrate on fine-tuning their agronomy. (Reid, 2006).

Tom Breen of Auscott succinctly outlined his reasoning:

GM cotton is no more than a tool. Its value is in the way it is used. *Bollgard II* is a constituent of our IPM program and *Roundup Ready* is a part of our IWM system. These have respectively allowed management of our worst pest, *Helicoverpa* and our worst weed, nutgrass. It is probably important to point out that we could still grow cotton successfully without GM varieties, but that it would demand more resources – more management time and more labour. (Breen, 2006).

Bruce Finney of the CRDC took a slightly broader view, citing increased economic security of farmers and the opportunity this provides for the pursuit of greater agronomic sophistication:

GM is a risk management tool. Without the worries of the past, growers can focus on managing things such as nutrients, irrigation and water efficiency. It enables them to move to another level of performance. ... In economic terms, it could be said that GM technology provides certainty in respect of risks, but that highly variable costs have become fixed costs. The licensing costs are paid irrespective of whether the season is difficult or easy. (Finney, 2006).

Possibly the most important economic consequence of the adoption of GM cotton has been arrest of the belief that cotton growing is environmentally unsustainable. Bt cotton reversed the fortunes of the Australian industry, blighted by its dependence on chemicals, launching it into the 21st century as a revitalised and respectable export sector (Australian Cotton Yearbook, 2006: 40). The technology has been described as a “quantum leap forward” (AFAA, 2004b) that “transformed” the industry (Perry, 2004, 1). While water consumption has now emerged as a major scientific and political challenge, without the industry’s current level of economic fitness, largely the result of advances associated with GM technology, the future of cotton in Australia would be very bleak.

Interviewees emphasised the importance of the reductions in chemical use for both farmers and the community. Peter Reid of the CSIRO said “It is true to say that GM – especially the Bt technology – has transformed the industry in

terms of pesticide use. The impact has been dramatic and very positive”. In respect of farmers and the demands that conventional chemical technology placed on them, he commented, “The lifestyle aspects are very significant for farmers.”

Bruce Finney, alluding to the perilous future faced by the industry prior to the introduction of biotechnology, said: “Bt cotton was pivotal to the industry’s retention of community acceptance and to its ability to manage pesticide impacts”. He described GM technology as “absolutely paramount” to the survival of Australian cotton farming (Finney, 2006).

Community Level

The economic impact of scientific regulation of GM cotton upon the cotton growing community can be related to the success of the industry following its introduction and the more positive regional image resulting from heavy cuts in chemical application. The establishment of precise economic links between the industry and the community would be possible, but is beyond the scope of this work. Bruce Finney (Finney, 2006) has described the continued health of the cotton industry as “imperative” for the region and given the size of the industry, there is no reason to doubt this.

National Level

Cotton is one of Australia’s most important primary products and with the

exception of the difficult (drought affected) 2004/2005 season, exports have generated over A\$1 billion every year since GM varieties were introduced (Cotton Yearbook, 2006: 42). The advantages of GM varieties to the cotton industry can be considered to have translated into national economic advantages through the generation of consistently increased economic activity and a strongly positive influence on the balance of trade.

While the vagaries of markets and climates mean that the seamless matching of supply with demand is an ideal, growers have far greater control over their crops with GM varieties, which makes marketing a far more stable and predictable procedure. Australia's reputation as a reliable source of high quality material is central to its ability to remain competitive. Tom Breen of Auscott considered consistency to be vital to the Australian industry and that Bt cotton was important in this respect:

In the past, annual variations in the yield impact of pests meant that there were "good" and "bad" years. In respect of this uncertainty, Bt cotton has taken the stress out of cotton growing. (Breen, 2006).

The current political crisis over water in Australia, precipitated by a severe, extended drought and fears that global warming will permanently deplete water resources, is a serious issue for the cotton industry and water use by the cotton industry has already been briefly discussed in Chapter 4. Cotton-growing is still popularly regarded as morally questionable and the GM-led rejuvenation of the industry might be argued to have placed undue pressure on the nation's water supply. However, while increased cotton production has

undeniably led to increased water consumption, the view that the suppression of cotton production would solve the problem of water in Australia is an uninformed one. This position takes no account of the way that water is managed and used or the surprising rapidity with which the water issue has ascended the political agenda.

The GM and water issues are essentially unrelated and can only be dealt with effectively if they are considered as such. At the beginning of the 1990s, close to twenty years ago, Australian trials of GM cotton commenced and eventually provided a solution to the serious and debilitating problems afflicting the industry and the region, namely chemical contamination of waterways and farms, inefficient pest control and resultant community division. The success of this work led to the restoration of the health and respectability of an industry that at the end of the day caters for basic human needs in the international market⁹.

⁹ As the product of a relatively easily cultivated plant, the utility qualities of cotton as a raw material for fabrics have for a long time ensured that it is consistently in demand and thus widely grown. Cotton lint, or raw cotton, is a natural product that is hypoallergenic (non-irritating) and is easily spun, blended and dyed. Fabrics woven from cotton are light in weight and resistant to staining and damage from sunlight. When appropriately handled, cotton fabrics possess an indefinite storage life. Clothing made from cotton is considered to have the advantages of being soft, light, cool and comfortable to wear (Cotton Australia, 2006: 2-4). Cotton also has the unusual quality of being able to absorb 27 times its weight of water. Over the course of the Seventeenth and Eighteenth centuries, cotton overtook flax and wool to become Europe's preferred source material for fabrics. Now the leading natural source of fibre, it currently comprises around 39% of worldwide fibre sales (Cotton Australia, 2006: 2).

Irrigation water has historically been controlled by water rights of varying security that were originally tied to land titles, and are used as farmers best see fit. If, for reasons of profitability and efficiency, they choose to use their legal water entitlement to grow GM cotton rather than say, pasture or canola, they are merely exercising their rights and judgment as primary producers in a competitive environment. Even though cotton is the major irrigated crop of its region and water availability has now emerged as a problem, it is illogical to treat cotton as the cause of that problem. The cause of the problem is, in the present light of a scarcer water supply, the over allocation of water rights, not the fact that 18% of Murray-Darling irrigation extractions are applied to a particular crop (Finney,2006). Australia has a limited supply of water that may be used for crop irrigation and since the market is notionally a free one,

Refined cottonseed oil is well regarded as a nutritious, edible oil and has been in common use for more than a century and a half. It contains no cholesterol, has high levels of polyunsaturated fat and antioxidant (vitamin E, which lengthens its shelf life) and has GRAS (Generally Recognised As Safe) status in the US (Cotton Australia, 2006: 3; OGTR, 2002:5). Cottonseed oil is widely used for cooking, especially in commercial frying blends, globally accounting for 40% of all cooking oils used (Cotton Australia, 2006:3). In Australia, cottonseed accounts for over a third (35%) of all edible oils sold (Marohasy, 2004:1). Cottonseed oil is also used to a significant extent in margarine production. In addition to its consumption as food, cottonseed oil is used in “soaps, emulsifiers, insecticides, cosmetics, pharmaceuticals, rubber and plastics” (Cotton Australia, 2006, 3).

Worldwide, average cotton consumption is 3.4 kg per head annually. In Australia the average is 8.4 kg per person. (Cotton Australia, 2006: 4). No part of the cotton plant is wasted. Even the stalks are useful and can be broken down and fermented for ethanol production or used as mulch or soil conditioner (Cotton Australia, 2006, 3).

the particular mix of irrigated crops in any given year is likely to represent the most profitable choices available to farmers.

Water was acknowledged by all interviewees from the cotton industry to be the major issue confronting it and was cited as a high research priority. Bruce Finney referred to the existence of “a significant, negative perception issue involving cotton and river health”, which he called a “misconception”. He pointed out that water quality is a more critical aspect of river health than water quantity and that water quality has been vastly improved by the introduction of GM technology (Finney, 2006). As far as quantity is concerned, he said that the accepted baseline of 2/3 of natural flow is being maintained in the rivers of the cotton-growing region, as opposed to the situation on the Murray, where 50% to 60% of natural flow is extracted.

At the farm level, total pumped water amounts to 5 to 8 ML/ha and the cotton industry is working hard to maximise productivity. On-farm efficiency gains in water usage are in the order of 2.5% to 3% a year. Ten years ago the industry was yielding 1 bale/ML and now it is 2 bales/ML. There are 330,000 ha of cotton grown in Australia with an export value of over \$1B annually. The health of the cotton industry is important to Australia and imperative for the region. (Finney, 2006).

Tom Breen, Auscott’s agronomist, considered the water issue potentially powerful enough to threaten the very existence of the cotton industry. He explained that the problem has three major components:

The first is water availability. The availability of a sufficient volume of water is critical. The second is security of supply, year in year out. Australia will not retain its place in the market if production volumes are not reasonably

consistent. It cannot survive if it oscillates from a crop value of \$3B one year to \$1B the next. The third is efficiency. If water is scarce, it is necessary to grow more bales of cotton to the megalitre. Ultimately, \$/ML, or return per ML will determine what can be grown where. (Breen, 2006).

The national economic consequences of GM technology are positive to the extent that following its introduction the industry experienced a prolonged period of prosperity and consolidation, which has only been checked by the combination of a long drought and a high Australian dollar. While there are broad concerns about the quantity of water that is diverted from Australia's waterways for agriculture, river water quality is much improved and efforts are being made to find solutions that will not be economically repressive. Had GM cotton not been adopted, the nation would now be confronting a very serious issue of water quality as well as that of quantity and might well be faced with the prospect of closing down a large and economically important industry.

The conceptual consequences of scientifically based regulation of GM cotton.

A regulatory program or decision can be perceived as a stimulatory event that affects perceptions concerning the matter subject to regulation. Scientifically based regulation sets out to identify and avoid problems on the basis of scientific analysis and understanding. Precautionary regulation seeks to avoid the risk of problems by disallowing the activity or technology in question. As the approaches are so different, official use of either is bound to affect current states of thought surrounding the subject matter in different ways and move

the relevant agenda in different directions. The state of research consequent to either type of regulatory action is, therefore, informative of the cultural value of the approach, as is its relationship with broader cultural aspirations. In the case of cotton, industry sources confirm that confidence in science has been strengthened by the success of GM varieties and that a vigorous program of new research is in place.

Interviewees from the cotton industry perceived GM Bt technology to be achieving effective *Helicoverpa* control, without the undesirable complications entailed in chemical control. They considered that research needs have moved beyond the initial problems addressed by the established GM traits and anticipated that GM technology would continue to provide significant technological advances. A general, informed expectation that it will contribute to the solution of current water issues was evident.

However, consolidation of the current technology remains the highest priority of CSIRO researchers. Peter Reid, a CSIRO cotton breeder, explained that although large steps forward have been made in the established GM fields, the work is unfinished:

Biotechnology is still focused on insect and herbicide resistance as there are still lots of ways to make the existing technology better. *Roundup Ready Flex*, for example, has considerable advantages over the older GM varieties, which can only be sprayed in the early part of the season if flower sterility is to be avoided. It will tolerate *Roundup* sprayed over the top for the entire season and has made the program much more useful. Very effective weed coverage is possible and more expensive and time-consuming weed control methods can

be avoided. Much breeding work is still being done with *Bollgard II*, particularly combining *Bollgard II* with *Roundup Ready Flex*. Work is also being directed towards varieties that combine Monsanto's Bt genes with Bayer's herbicide (glufosinate) gene. (Reid, 2006).

He indicated that cutting edge research in the larger biotechnology corporations has moved on, citing "plant resistance to stresses such as heat stress and water stress", although commercially applicable solutions in these areas are still "some years off" (Reid, 2006). CSIRO, he explained, is not involved in this work as it does not have the corporate skills and resources necessary to support major research projects involving the identification of commercially important, patentable genes. It does, however, maintain a modest level of such work and, in respect of cotton, is investigating ways of "modifying oils, enhancing fibres and improving waterlogging characteristics" (Reid, 2006).

Tom Breen of Auscott perceived industry needs to be changing. He spoke of the ravages of caterpillars as a historical difficulty and described the current problems and doubts concerning water as the most demanding issue:

Now the variable with the biggest impact on crop yields is water, so developments relating to water use and management, such as tolerance of drought and tolerance of water-logging are being sought. (Breen, 2006).

Bruce Finney referred to the ongoing development of "more robust and longer-lived technologies for the existing ... traits," but also foresaw a major future role for biotechnology:

The importance of GM to the industry is currently very large and it seems likely that this will continue to be the case in future ... issues of resistance will probably be at the forefront – characteristics such as drought tolerance, water requirements, water logging. Climate change and its connotations means that there would be a lot of interest in water related modifications. (Finney, 2006).

He also identified a range of less pressing, longer term prospects for the application of biotechnology to cotton, such as oil and fibre modifications and resistance mechanisms for diseases and sucking pests (Finney, 2006).

The information provided by these industry representatives is clear and consistent. Existing GM technologies are regarded as having largely overcome the industry's traditional major difficulties, enabling new research priorities to emerge. Since the introduction of GM varieties, the focus of biotechnological research has changed, initially concentrating on the refinement and enhancement of the technology. The introduction of the superior *Bollgard II* and *Roundup Ready Flex* and the moderation of some regulatory requirements affecting growers are outcomes this work.

Water consumption is the cotton industry's next major challenge and its members are refocusing on this issue. As mentioned in the case study, Monsanto has already licensed a GM cotton variety, modified for reduced water consumption, and research is ongoing¹⁰ (OGTR, 2007).

¹⁰ Fred Perlak, Monsanto's Director of Cotton and Specialty Crop Technology, in 2006

Chemical contamination by the cotton industry was a major tension in the Australian agricultural community for many years, but is now almost completely an issue of the past. The lack of public concern that GM technology provided the means for this change is self-evident. It is also self-evident that climate-change and water currently are the most urgent political problems in rural Australia. GM technology has eased public anxiety about chemicals, allowing the R&D resources of the cotton industry to initiate new research in accord with the needs of growers and the concerns of the community.

The social consequences of scientifically based regulation of GM cotton.

The social consequences of the adoption of GM cotton are most immediately and importantly felt in the communities where cotton is grown. These communities bore the brunt of chemical insect control for many years and the introduction of GM cotton is invariably reported to have healed community divisions. Interviewees strongly emphasised the difference in the industry's relationship with the public since the adoption of Bt cotton.

Bruce Finney reported that local communities had reacted "very positively" and that they were now "very supportive" of the industry. He described the

described these trials as being at "the 'Proof of Concept' stage" which aims to determine "if these genes do improve performance under such stress conditions", but added that Monsanto would not anticipate commercial release before 2013 (Cotton Yearbook, 2006: 32).

problems of noise, odours, fish kills and high chemical levels, which had previously led to complaints and bad feeling in the community as “a thing of the past” (Finney, 2006). He also reported that, as far as he was aware, no difficulties had arisen within farming communities over the use of GM cotton, “There is resistance from NGOs, but to my knowledge, not from other producers” (Finney, 2006). Adam Kay, of CSD said, “The cotton farming community now has a much better relationship with the general community. The issues of fifteen years ago have completely disappeared” (Kay, 2006).

These observations appear to reflect acknowledgement within communities that the industry has responded to and resolved their concerns over chemical insecticides in a way that is understood and appreciated. After a dozen years of use, the absence of any unforeseen problems with GM cotton has reassured communities and no serious opposition to it has developed.

This explains, in a logical sense at least, the absence of substantial political reaction to the introduction and continued use of GM cotton at any level of government. The CSIRO’s Peter Reid said, “Cotton has had a dream run. There have only been a few minor difficulties with groups opposing it. Working with other crops, such as canola, would be very frustrating” (Reid, 2006).

The unblemished record of GM cotton has silenced most criticism and recent published material suggests that GM cotton opponents are now avoiding the issue of the technology and focussing on more conventional aspects of environmental and cotton politics. A 2006 news report of reaction to proposed trials of GM cotton in the Ord River irrigation area is remarkable for the lack of emphasis of the risks of GM technology. The item reported that “the groups, including Environs Kimberley and The Environment Centre in the Northern Territory say commercial cotton growing involves massive land clearing and could lead to river pollution” (Bigpond News, 2006). The only hint of genetic hazard was from an environmentalist quoted as alleging that GM cotton could “become a weed” (Bigpond News, 2006). While such unspecific and weakly supported claims may well concern some members of the community, they are a far cry from the alarming and provocative assertions associated with GM canola.

The use of high quality science as the main regulatory guide for the introduction of GM cotton appears to have been entirely satisfactory. Commercial experience has confirmed the integrity of the science and the new technology, and community tensions arising from the previous heavy use of insecticides have been resolved.

Genetically Modified Canola

The direct consequences of the precautionary regulation of GM canola.

The primary consequence of bans on commercial GM canola crops is the confinement of canola production to conventional varieties grown with selective herbicides or to TT (triazine-tolerant) and IT (imidazolinone-tolerant) varieties grown with non-selective herbicides. This in turn has two major, direct effects.

The first is that significant quantities of technologically outmoded, environmentally undesirable and often expensive agrichemicals are routinely introduced to the environment by canola farmers. In comparison, the alternative of GM technology would involve the use of either glyphosate or glufosinate, both of which are cheap, environmentally “soft” herbicides. As has been explained in the case study, both are of low toxicity, are relatively immobile in the soil and are quickly degraded. As in the case of GM cotton, the effects of the use of these chemicals are discussed below as impacts on soil, water and the open-air environments.

The second important result of the ban on GM canola is that Australian canola yields are smaller and of lower quality than those of competitor nations such as Canada. The implications of this are that the Australian canola industry is operating at a disadvantage in the international market and that canola is a less attractive crop for Australian farmers than it would

otherwise be. It is therefore less likely to be grown and the industry is less likely to attract investment or research funds. These matters are considered further under the appropriate headings.

Influences on the soil

There are two major issues pertaining to agricultural soils that typically arise with non-GM canola cultivation: (a) excessive mechanical soil operations and (b) herbicides that persist in the soil beyond the life of the crop.

(a) Typical disadvantages associated with excessive soil disturbance are the potential for soil structural damage, carbon loss, nutrient and moisture depletion, erosion and long-term productivity losses arising from these factors (Norton, 2003: 15-16). In most Australian soils, traditional crop cultivation practices are not sustainable and in less stable soils, not possible at all. Increased operating costs, resulting from associated extra labour and energy requirements cut into farm profitability and production capacity. These factors have been well understood for many years and conservation cropping systems such as “reduced tillage”, “minimum tillage” and “no till” (or “direct drilling”) management systems have long provided models for broadacre cropping enterprises¹¹. Herbicide tolerant crop traits allow the economies of conservation farming practices to be maximized and in

¹¹ A Canola Council of Canada (CCC) study over the period 1997-2000 found that use of GM canola in that country has resulted in a 50% reduction in cultivation passes over an area of 1.05 million hectares and that reductions in total field operations saved 31.5 million litres of fuel in the 2000 growing season (Norton, 2003: 18).

Australia TT canola is frequently “direct drilled”, although tillage cannot be avoided in every situation (Norton, 2003: 15).

In an analysis of the likely effects of the introduction of GM canola to Australia, Melbourne University canola agronomist, Dr Robert Norton, estimated that at a 52% rate of uptake and with 80% of the GM crop direct drilled, the technology would be “expected to increase the area of canola grown under no-till or minimum tillage farming systems by 200,000 hectares (Norton, 2003: 15). Norton calculated that profitable canola production would also become feasible on an estimated 160,000 hectares of arable land that currently cannot support profitable canola crops (Norton, 2003: 15). By removing the GM canola option, the State moratoriums compel a substantial portion of those farmers who do not grow herbicide resistant canola to adopt cropping systems that involve increased cultivation, thus promoting accelerated soil degradation and loss. Although the associated cost burden is far too complex to be precisely quantified, it is clear from the above that it must constitute a significant and ongoing economic drag on producers.

(b) Norton’s comparison of the herbicide demands of the various canola production systems (see Table 8.2) presumes an initial application of a pre-emergent weed control chemical at the time of sowing in all cases including

Table 8.2

System	Pre-emergent	Pre-sowing	In-crop	In crop
Conventional	Trifluralin	Glyphosate	Clopyralid	Clethodium
TT	Simazine plus Atrazine	Glyphosate	Atrazine	Clethodium
IT	Trifluralin	Glyphosate	Imazapic plus Imazapyr	
InVigor®	Trifluralin		Glufosinate	
Roundup Ready®	Trifluralin		Glyphosate	

Canola production systems and typical herbicide use (after Norton, 2003:10).

GM systems. Australian GM canola systems are assumed to retain one initial application of trifluralin¹², to which canola has a natural tolerance, as an anti-resistance measure (Norton, 2003: 11), since the repeated, exclusive use of a single chemical or chemicals from a single herbicide group applies a dangerous level of selective pressure to weeds.

¹² Pre-emergent herbicides, by the nature of their activity, tend to quickly bind to matter in the surface layer of the soil and trifluralin becomes strongly fixed within a few hours of application. Once incorporated it is considered to be “immobile in the soil” (Johnstone et al, 1998: 364), which, given its low ecotoxicity, minimizes any opportunity for it to cause environmental damage. It degrades over time, however, and does not accumulate in the soil even with repeated annual applications (Johnstone et al: 363). However, under certain weather conditions its persistence may be extended and in these circumstances it can affect subsequent crops if they are sown directly into the surface layer of the soil. It is thus not a perfect solution to the difficulty of resistance, but since a pre-emergent herbicide application is common to all current growing systems, in this respect there is no advantage to either GM varieties or the alternatives allowed under the precautionary bans.

Glyphosate is applied as a pre-sowing knockdown herbicide in the three non-GM canola production systems (conventional, IT and TT) (Norton, 2003: 10). Subsequent herbicide applications may involve combinations involving atrazine, clethodim, clopyralid, imazapic, imazapyr, simazine or the previously mentioned triflurolin (Norton, 2003: 10). Of these, atrazine and simazine have been implicated in water contamination, the appearance of resistant volunteers in subsequent crops and carryover in the soil at levels hazardous to following crops - all matters that have been discussed in the canola case study. Triflurolin is potentially a hazard to aquatic life (UFC, 2005) but due to its pronounced immobility in the soil, would not normally pose an environmental threat.

As has been pointed out in the case study, imazapic and imazapyr have been compromised by the development of resistance¹³ in some weeds and they have also been implicated in soil carryover injury¹⁴ (Peterson et al, 2001: 11). Emerging weed resistance to clethodim has been reported by the Western Australia Herbicide Resistance Initiative (WAHRI, 2007). Clopyralid, an in-

¹³ Weed resistance to herbicides is of environmental concern, partly because it is likely to result in the use of heavier application rates and/or the use of harsher chemicals in order to achieve effective weed control.

¹⁴ Conventional canola cannot safely be sown in the same ground for 34 months after these chemicals have been applied (Norton, 2003: 4). Canola resistance has also presented some difficulties for growers with reported instances of volunteers appearing as resistant weeds in subsequent crops when the same chemicals are used.

crop, broadleaf herbicide, has not so far been reported to be hazardous in the soil or to have resistance or carryover problems, but is expensive.

With the exception of the expensive broadleaf herbicide clopyralid, the chemical alternatives to glufosinate and glyphosate (used in GM systems), involve either direct undesirable impacts on the environment, or the likelihood of such impacts and are not compatible with sustainable, conservation farming models. The hypothetical alternative of organic canola production it is not a realistic agronomic proposition¹⁵, so in the absence of the GM option, farmers are obliged to use these herbicides.

Influences on environmental water

The propensity of certain agrichemicals to move from the point of application to environmental water is well known. Farmers producing canola along conventional lines have benefitted from the development of environmentally “soft” selective herbicides, such as clopyralid and clethodim that lend themselves to conservation farming systems without presenting issues of biosafety. Trifluralin, which is very toxic to many aquatic organisms, is environmentally acceptable if it is not misused, only because it fixes strongly and immediately to soil components and degrades without shifting. As has been outlined in the case study, glyphosate is of low toxicity to fish, is

¹⁵ Organic systems involve mechanical forms of weed control, such as mulching and cultivation, which are not regarded as practicable on the scale required for canola.

virtually immobile in soil and is the herbicide of preference for weed control in wetlands. Conventional canola production need not lead to contamination of environmental water if sensitivity is exercised in the choice of crop situation, chemicals and farming practices.

IT canola, which is resistant to imidazolinones does not appear to have been linked to issues of water contamination. Victorian DPI advice published on a poster produced for the cropping industry is that the chemicals usually used, a combination of imazapyr and imazapic sold as *Midas* or *On Duty*, are “very slightly toxic” to humans, fish, insects and birds (DPI, 2003).

TT canola involves the use of the triazines simazine and atrazine. The environmental hazard associated with these chemicals arises from their solubility, which results in fairly free movement into ground water. This topic has been covered in the canola case study. As a consequence of this tendency and longstanding concern about their biosafety, the use of triazines is now discouraged in most farming sectors and their continuing registration is a matter of political contention.

In spite of the considerable agronomic disadvantages of TT canola that have been previously described, in the absence of the option of using GM varieties, it is the most economically viable choice available for many farmers. TT canola dominates the Australian canola industry and its use is

increasing, probably as a direct result of the moratoriums. Dr Robert Norton (2003: 4) calculated that TT canola comprised 55% of the Australian crop area in 2002 but according to the OGTR this had risen to “60 – 70%” of the total by the 2005-2006 season (OGTR, 2007b: 47).

In 2003, Norton estimated that the introduction of GM canola would halve the area of TT canola grown, reducing the environmental triazine burden by 640 tonnes of herbicide concentrate annually. Conversely, the moratoriums on GM canola that prevent the replacement of TT canola can be considered to be responsible for continued use of these herbicides by the industry at very high and increasing levels. It could reasonably be assumed that adoption of GM canola at a similar level to Canada would reduce triazine use in Australia by something like 1000 tonnes annually and open up the possibility of phasing out TT canola entirely. This would in turn lower triazine contaminant levels in environmental water downstream of canola growing areas. Canola represents 40% of the non-cereal broadacre crop area in temperate Australia so the relinquishment of TT varieties by the canola industry would be a major step towards the complete elimination of triazines from Australian agriculture.

Influences on the open (or “air”) environment

The universal use of GM canolas would confine herbicide applications in canola crops to one application of trifluralin and one application of either

glyphosate or glufosinate compared to the four applications typical of current systems (Norton, 2003: 10). If hypothetical GM uptake in Australia is assumed to mirror Canada's rate, where over 85% of the canola crop is comprised of GM varieties (Grains Council of Australia, 2007) the existing moratoriums on GM canola can be considered to be responsible for 85% of the current herbicide applications. While there is no evidence of serious damage to organisms inhabiting the open-air environment as a consequence of use of these chemicals, every agricultural spraying operation enlarges the environmental footprint and exposes operators and others to unpleasant chemicals. Any reduction at all in the range of chemicals used and the frequency with which they are applied can be considered to be environmentally desirable.

Norton's comments apropos increased energy costs arising from extra tillage and spray operations associated with non GM canola production (Norton, 2003:15-18) and the Canola Council of Canada (CCC) finding that GM varieties saved 31.5 million litres of fuel in Canada in 2000 (Norton, 2003:18) have already been cited. No attempt will be made here to quantify the extra fuel used or the added atmospheric carbon loads attributable to the moratoriums on GM canola in Australia. However, the Canadian experience of 50% fewer cultivation passes and Norton's model showing 50% fewer spraying passes (Table 8.3) suggests that theoretically fuel consumption and carbon loads might be halved by universal use of GM varieties.

The fact that GM canola is not grown in Australia has direct effects on the quantity and quality of canola produced from the area under the crop. Both yield/ha and oil content of Australian canola crops are significantly below the levels attainable with GM technology. As the consequences of those differences are almost entirely economic, they will be considered below under that heading.

Table 8.3

Chemical or group	Is carryover to following crops A problem?	Is weed resistance a problem?	Is movement into water table likely?	Other
Trifluralin	Yes	Increasingly	No	Dangerous to aquatic life. Inexpensive.
Triazines (Simazine Atrazine)	Yes	A major issue.	Contaminates and moves in water.	Very persistent in soils. Inexpensive
Imidazolinone (Imazapic Imazapyr)	Sometimes	A serious issue. Only suppresses some weeds.	No	Low toxicity. Drift risk. Slow acting. Very expensive.
Clopyralid	No	No	No	Broadleaf . selective. Low toxicity. Expensive.
Clethodium	No	Emerging as a problem.	No	Grass selective. Low toxicity. Expensive.
Glyphosate	No	Exists, but not a serious problem.	No	Broad spectrum Low toxicity. Inexpensive.
Glufosinate	No	No	No	Broad spectrum Low toxicity. Expensive.

Summary of major risks associated with the herbicides most commonly used in canola production systems

The economic consequences of the precautionary regulation of GM canola.

Enterprise Level

Influences on farm profitability may be considered as (a) general economic effects and (b) specific economic effects.

(a) The effects of excessive paddock operations upon the long term fertility and productivity of soils has been alluded to above and it has long been accepted that such degradation can severely inhibit the ability of soil to support optimum crop yields. Long term fertility decline is insidious and often irreversible. In such circumstances, residual herbicide carryover and/or poor weed control are, if present, likely to further depress crop yields. These factors, associable with older canola growing technologies, must certainly affect many enterprises and substantially reduce the overall profitability of many farms. However, accurate quantification of these costs would constitute a major challenge that is well beyond the scope of this analysis.

(b) The main economic differences between GM and non-GM canola production are a product of differences in input costs and in returns.

Table 8.4

	Conventional	Roundup Ready®
Expected Yield	1.8t/ha	2.2t/ha
Net Price \$/t on farm	\$400	\$400
Gross Return	\$720/ha	\$880/ha
Seedbed Preparation and Sowing	\$14/ha	\$14/ha
Seed Costs	\$15/ha	\$40/ha*
Fertilizer Costs	\$72/ha	\$72/ha
Herbicide Costs	\$57/ha	\$22/ha
Insecticides	\$6/ha	\$6/ha
Windrowing and Harvesting	\$38/ha	\$38/ha
Insurance	\$10/ha	\$10/ha
Local cartage	\$10/ha	\$10/ha
Total Costs	\$222/ha	\$212/ha
GROSS MARGIN	\$498/ha	\$668/ha

Comparison of typical conventional and GM canola costs and returns per hectare.
Key: * = includes royalties. (After Norton, 2003:22)

These differences are illustrated in Table 8.4, which compares the cost structure of Monsanto's *Roundup Ready* canola system with a typical conventional cost structure and demonstrates in broad terms the cost advantages of GM growing systems.

Table 8.5 below enables some level of comparison to be made between the varying herbicide costs incurred in different management regimes, but some caution should be applied in interpretation as the complexities of yield and quality and situation can alter these models. IT and *Invigor* canolas, for example, which have high chemical costs, typically have superior yields, whereas TT canola typically has poorer yields and lower oil content.

Table 8.5

	Conventional	TT	IT	Roundup Ready®
Herbicide				
Trifluralin	\$14.00	\$07.50	\$14.00	\$14.00
Glyphosate	\$07.50	\$13.50	\$07.50	
Simazine		\$13.50		
Imazapic + Imazapyr			\$45.00	
Atrazine		\$18.00		
Glyphosate				\$07.50
Clethodim	\$18.00		\$18.00	
Clopyralid	\$17.50			
TOTAL/ha	\$57.00	\$52.50	\$84.50	\$21.50

Comparison of herbicide costs per hectare under different systems.

(After Norton, 2003:22)

Oil content is a critical quality parameter for canola growers and the low oil yield of TT canola seed also affects returns:

The lower oil content of TT canola is a significant problem for Australian exporters, particularly canola from Western Australia where TT canola is dominant. Western Australia has met the 40% domestic standard in recent years, but the export standard for seed oil content is 42% and to consistently

meet this will be an ongoing challenge. The increase in oil content brings growers a 1.5% price bonus (or deduction) for each one percent increase (or decrease) in oil content above (or below) the export standard. (Norton, 2003:13).

Malcolm McKenzie, a livestock and grain producer from Wagga Wagga in southern NSW, grew both *Invigor* and *Roundup Ready* GM canola crops in comparative production trials alongside currently grown varieties. He typically cultivates about 480ha (1200 acres) of canola as well as wheat, barley, lupins, peas and oats. McKenzie described the importance of canola to the maintenance of wheat yields¹⁶.

Canola is not only a profitable crop in its own right, but it is strategically valuable, as it has an anti-pathogenic function and breaks the root disease cycle that tends to build up in cereal crop rotations. In the 1980s, we were growing around 400 ha (1000 acres) of wheat and we were lucky if we achieved a yield of 2.5 tonne/ha. ... The introduction of canola ... led to this figure virtually doubling. This meant that we were able to halve our acreage of wheat and still maintain our production level while turning the other half over to canola. In effect, canola improves the bottom line of grain growing. It increases productivity. (McKenzie, 2006).

¹⁶ In a 1999 analysis of farm-level economics of canola production in southern NSW, Scott, Brennan and Faour (1999) identified a positive correlation between the profitability of canola and the extent to which it is retained in crop rotations. When yields and returns fall, its prevalence in rotations also falls. This very logical link is quite important since wheat following canola has been shown to have “a 20% yield benefit over wheat following wheat” (Norton, 2003: 7). This is related to factors associated with soil-health and its nutritional status, some of which have been considered in the canola case study. It is estimated that the yield benefit of canola preceding wheat in rotations is in the order of half a million extra tonnes of wheat a year, with a value of some \$100M annually (Norton, 2003:7).

Norton's model¹⁷ for GM canola performance in Australia is predicated on conservative values. It assumes that GM varieties would replace 50% of TT canola and 40% of conventional canola while IT canola production would not be affected at all (Norton, 2003:19). Since Canadian GM uptake¹⁸ is 85% of total (Grains Council of Australia, 2007), Norton's projections can be regarded as the most pessimistic of likely outcomes.

Wagga Wagga crop farmer Malcolm McKenzie said that non-GM canola "demands the use of selective herbicides involving more operations and greater herbicide expenses". He described the reduced herbicide costs associated with GM canola (\$12/ha for *Roundup Ready* as against \$40-45/ha for TT canola) as "on its own, a huge benefit. The further advantages of increased yield and ease of management make the GM option even more attractive". The "overall economic benefit" of the GM varieties "amounts to 15% to 20% when both increased yield and cost savings are taken into

¹⁷ Economic benefits could be expected to be accrued through canola yield increases arising from earlier sowing dates (5%), enhanced weed control (8%), avoidance of 20% TT canola yield penalty (across the board increase of 0.1t/ha), avoidance of 2-3% TT oil penalty (across the board increase of 0.6% oil content), improved viability of some marginal cropping country and a "rotation benefit" (Norton, 2003:21) to wheat yields. Norton estimated that gross margins for GM canola could be up to \$170/ha more than for conventional canola grown under the same conditions (Norton, 2003:19-21).

¹⁸ A 2001 Canadian study of GM canola outcomes reported that growers recorded 10% yield increases over conventional varieties, cleaner grain samples and a 40% reduction in herbicide costs (Canola Council of Canada, 2005).

account” (McKenzie, 2006). He considered his own future economic viability as a farmer was dependent upon GM technology becoming available:

From a farmer’s perspective, the basic fact of life is that profitability in a competitive environment is absolutely critical to survival. The GM varieties offer very significant production advantages, which we will need if we are to remain viable. Market prices assume a certain level of productivity on the basis of what is available. (McKenzie, 2006).

At the enterprise level, precautionary bans on GM canola deny farmers access to a technology offering very significant productivity and management benefits.

Community Level

If the moratoriums on GM canola have had a depressing effect on farmers in the canola industry, regional economies will have suffered also. The extent to which this might have affected communities since the time GM canola varieties became a possible option is difficult if not impossible to establish. Canadian experience suggests that the benefits of GM canola to communities include “added investment in canola crushing capacity; improvements in the local seed, herbicide and equipment industry; and added shipping, handling and marketing, etc” (Canola Council of Canada, 2005). While it is incontestable that farm income in the cropping regions would have been enhanced by the availability of GM technology, the level of community benefit that has been sacrificed is less clear, especially since drought has affected Australia at the continental level for most of this period.

Norton estimated the annual value of the direct economic benefit of GM canola to be \$135M (Norton, 2003:21) but in the context of a 2003-2004 agricultural commodities value of \$36.9B (ABS, 2005:4) this is not a massive sum. Although Norton's figure is probably conservative, an extra \$135M spent across the local communities of Australia's temperate cropping regions, would have little impact without complimentary positive factors such as good seasons, a climate of optimism and a rising canola market. However, the sheer gains in efficiency made possible by GM canola would be such a dramatic step forward for grain producers, that their introduction could in itself be considered an important confidence booster for temperate agriculture generally. A detectable level of growth in economic activity might take some years to emerge.

National Level

For Australia, the superficial economic consequence of the moratoriums against GM canola is that the nation has foregone an uncertain but probably significant volume of canola production and a slightly smaller export trade volume. However, there are some indications that the position of Australia may have been more severely compromised.

Norton's 2003 figures seem to be very reasonably supported, if conservative, and closer examination suggests that his projections certainly do not

exaggerate the cost of the moratoriums to Australia. Norton assumes a value of \$400 a tonne for canola, but ABARE's *Australian Commodities* magazine, for the December quarter of 2007 reported that "Australian canola prices are forecast to average \$585 a tonne in 2007-08" (ABARE, 2007). On this basis, the national deficit arising from the moratoriums might be thought to be considerably greater than the \$135M suggested by Norton in 2003 (Norton, 2003:21). A revised estimate, published by Norton in a media release in November 2007, places the value of the benefit of GM canola to the grains industry at \$157M (Norton and Roush, 2007).

Although direct comparison with the performance of other nations has some serious limitations, the differences in the fortunes of the Canadian and Australian canola industries since 1996, when GM canola was first grown in Canada, are quite striking and must be considered. According to Dr Norton and Professor Rick Roush, both of the Faculty of Land and Food Resources at the University of Melbourne, since GM technology was introduced, Canadian production "has increased by 40% and average yields have increased by 27% ... [while during] the same period, Australian yields have declined by 10%" (Norton and Roush, 2007).

Andrew Broad, a Nuffield scholar who visited eight countries during the course of a 2006 international on-farm study of canola production, contrasted falling canola acreage and static yields in Australia with increasing crop area

and dramatically increasing yields in Canada (Broad, 2007). Although both countries are prone to erratic production patterns due to harsh climatic conditions, since 1980 the trend of Canadian production has consistently been upward, whereas Australian production has shown a pronounced downward trend since the peak year of 1999-2000 (Foster and French, 2007:17).

Table 8.6 records recent Australian and Canadian canola production in kilotonnes. Comparison of the five-year averages of the earliest and latest figures in the series shows that Canadian production grew by 18.9% from the 1997-2001 period to the 2003-2007 period, while Australian production simultaneously declined by 27.0%. Had Australian growth equalled Canada's, the most recent five year average would have been 1763 kilotonnes, a figure that has not been reached at all since 1999-2000. Although it is quite true that many factors, notably drought, can disproportionately influence such a simple trend indicator, it is also true that this record can give no comfort to canola growers because a fundamental problem of some sort at the industry level is clearly evident.

Table 8.6

Season	1997 1998	1998 1999	1999 2000	2000 2001	2001 2002	2002 2003	2003 2004	2004 2005	2005 2006	2006 2007	2007 2008
Can Yield '000t	6393	7643	8798	7205	5017	4521	6771	7674	9483	9000	8751
Aust Yield '000 t	855	1690	2460	1334	1130	972	1005	1531	1436	513	* 931

Canola production in Australia and Canada 1997-2008 in kilotonnes. (Sources: ABARE, 2006; ABARE, 2007; ABS, 2002; AOF, 2005; Canola Council of Canada, 2007; Nelson et al 2001:5). Note: Australian canola seasons straddle two calendar years. Canadian data is relevant to the crop of the earlier mentioned year. Key: * = estimated

On the face of it, ignoring the severely dry years, it is difficult to avoid the conclusion that the Australian canola industry has at best stagnated since 1999-2000 and that this tendency could most easily and obviously have been countered by introducing GM varieties. It is not possible to tell what the decisions of the States not to do so has cost Australia economically but from an economic standpoint, a price has been paid by the nation and the November 2007 decisions in Victoria and NSW to allow the technology to be used was a long overdue admission of this.

The conceptual consequences of the precautionary regulation of GM canola.

Malcolm McKenzie observed in 2006 that from his perspective, canola research appears to have reached a standstill in Australia.

As a grower relying on the continuing productivity of crop varieties, I am very aware that conventional plant breeding sources are offering us nothing. There are simply no new varieties coming along. In terms of productivity, there has been no gain from conventional varietal improvement in the last twelve or fifteen years. (McKenzie, 2006).

This view is consistent with the findings of the 2007 Review of the Moratorium on Genetically modified Canola in Victoria which

... received a clear message that investment in research and development in both public and private sector canola breeding – and, more broadly agricultural science – has been significantly hampered as a result of the moratorium. (Nossal, Forster and Curnow, 2007:53).

The review panel described a shift, during the 1990s, of plant breeding activity from the public to the private sectors, and a de-emphasis of

conventional varietal development in the wake of the success of GM technology on North America. In this context,

the introduction of state and territory government moratoria in 2004 significantly affected public and private sector canola breeding programs. The moratoria have prevented private and public sector technology developers from commercialising their products, and forced them to incur significant losses on their investments. (Nossal, Forster and Curnow, 2007:53).

The panel's analysis of impacts on "science research and development" (Nossal, Forster and Curnow, 2007:Chapt 7) identified a number of concerning R&D trends,¹⁹ which together amount to a serious erosion of research capacity²⁰ that would only be slowly reversed by the lifting of a moratorium.

¹⁹ These are in most cases the product of a number of interacting factors including: long research lead times, the rundown state of research facilities, losses of research investment, the loss of investor confidence, the loss or delay of conspicuous benefits of research (such as better community health outcomes), reduction of the Australian canola industry to a less representative and less competitive state, disengagement of Australian research from international collaboration, losses of "key Australian scientists to competing research programs overseas" (Nossal, Forster and Curnow, 2007:55) and disincentives for young scientists to enter plant science and agriculture (Nossal, Forster and Curnow, 2007:Chapt 7).

²⁰ The submission of Nufarm Ltd, a company involved in seed R&D and production, cited the difficulties of "reduced investment in seed development [and] ...an increased cost and regulatory burden" as major problems for research (Nufarm, 2007:3). It warned that it would "be forced to re-evaluate its on-going investment in the Australian seed industry, particularly with regard to R&D directed towards the development and commercialisation of GM canola" if the moratorium was extended" (Nufarm, 2007:5). In Nufarm's estimation "Australia's canola development pipeline is now 5 to 10 years behind that of Canada" (Nufarm, 2007:3).

In evidence to the panel, the CSIRO expressed concern at “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” (Nossal, Forster and Curnow, 2007:55). The CSIRO’s submission pointed out that “GM technology is not just a tool to develop GM crops, but is also a critical research technology, which ... underpins all of our modern bioscience” (Nossal, Forster and Curnow, 2007:54).

The panel’s report describes a research sector characterised by incipient international isolation and reduced relevance, due to losses of investment, capability, knowledge, resources and cutting edge projects. Implicit in the rundown of Australia’s canola research capability is the likelihood that other associated fields of research will also suffer setbacks.

The social consequences of the precautionary regulation of GM canola.

The precautionary bans on GM canola have prevented Australian farmers from accessing the technology and thus remaining abreast of the most advanced international standards of canola production. This disadvantage and the absence of a regulatory mechanism to resolve deadlocks has meant that political conflict has persisted over a long period. The removal of the NSW and Victorian moratoriums in November 2007 was the consequence of persistent pressure from GM advocates and clear evidence of mounting

economic damage, not an admission of error from opponents of GM crops. There is little in the data to suggest that any direct benefit has flowed from the canola moratoriums.

Genetically Modified Carnation

The direct consequences of scientifically based regulation of GM carnations

Scientific analysis has established that the risks involved in the commercial production of blue carnations are minimal. Consequently, six varieties have been licensed and are currently grown and sold in Australia, although not in large volumes. Some of these varieties are now available to domestic gardeners.

Since blue carnations have been modified with petunia and pansy genes, there can be little if any likelihood of any environmental impacts that would not be associable with normal carnation, pansy and petunia cultivation. In any case, commercial flower production of this kind is normally, if not invariably conducted in contained and controlled environments (that is, in a growing medium within a greenhouse) so opportunities for movement of material into the wider environment is minimal.

Consequences for the soil

The total area of blue carnations commercially cultivated in Australia is less than 10ha, which is a smaller area than many individual floriculture

businesses cover. There is no reason to suppose that the modifications for flower colour should have hazardous effects on the soil and no such risk is discussed or reported in the available literature.

Consequences for environmental water

No hazardous effects on environmental water are hypothesised or reported in the available literature.

Consequences for the open or “air” environment

The risk of the movement of carnation pollen or other reproductive material into the open environment is minimal, as factors outlined in the case study would indicate. The various biological limitations to the reproduction of carnations mean that accidental seed production is highly unlikely. The containment in greenhouses of commercial blue carnation crops would greatly inhibit the dispersal of plant matter into the open environment. Flowers are harvested as opening buds before pollen is mature. There is anyway no established reason to consider this material dangerous to humans or other organisms.

Economic consequences of scientifically based regulation of GM carnations

Since the Australian market for blue carnations is obviously relatively limited, the economic return to growers from this GM group is never likely to be very great. However, the very large markup on the retail value of cut

flowers, which can cost well over \$100 for an arranged bunch, means that a potential exists for them to generate economic activity worth many times their farm gate value. Unfortunately for this research, the great difficulty of obtaining any information at all about blue carnations from the industry means that it is not possible to ascertain the current value of the technology. The OGTR's April 2007 announcement of the placement of four blue carnation varieties on the GMO register included the information that 4.5 million blooms had been sold in Australia since the first variety was licensed in 1995 (OGTR, 2007c). Without more economic detail, such as farm gate prices and the magnitude of retail revenue, however, this information is of very limited value.

Ownership of the patent on the gene presumably holds the potential for very significant long-term earnings, especially if the current application of the technology in carnations and roses is extended to include other flowers. The Florigene website lists the particulars of wholesalers of its blue carnations in Canada, United Arab Emirates, Ecuador, Germany, Holland, Japan, Puerto Rico, Sweden, UK and over 40 across the USA (Florigene, 2008). The global stretch of the market for these flowers suggests that at least the potential exists for substantial sales growth to occur well into the future.

Enterprise Level

No specific information is available, but blooms are being grown for the market and plants have been advertised for home gardeners in Victoria.

Community Level

There is no indication that blue carnations have so far had any significant impact at the community level and insufficient information is available to make any definite assessment of economic activity. However, 4.5 million blooms over twelve years does not seem a large enough basis for the generation of substantial economic activity at either the industry or community level, even if the markup on them multiplies their value many times. It is nonetheless, possibly a significant figure for Florigene, which receives royalties for blue carnations that are presumably proportionate to sales of blooms.

The systematic, if gradual, expansion of Florigene's range of GM flowers suggests that turnover of these products is also expanding and that this trend is likely to continue. As long as the developmental work goes on and sales grow, at some point horticultural communities, such as those in the Dandenongs near Melbourne, are bound to be economically affected. While GM flowers may to some extent create new revenue and "grow" the flower market through their novelty, they will ultimately need to take existing

market share from other flower lines if the technology is to become a permanent part of the industry.

National Level

At the national level, the economic impact to date cannot be considered significant. However, the growing international market, especially that in the US, suggests that the potential exists for the development of a very large export market. Other applications of the technology would conceivably multiply this further. Presumably the recent sale of Florigene to Suntory could ultimately see the economic benefits of the original research and development flowing to Japan rather than Australia.

Conceptual consequences of scientifically based regulation of GM carnations

The conceptual consequence of the scientific regulation of GM carnation is that the research agenda of this particular area of biotechnology has been free to move well beyond the original goal of developing a blue rose and to open up and explore new fields of science. The cutting edge of Florigene's work moved at an early stage into the broader genetic fields of flower pigment formation and cut-bloom senescence. The knowledge gained was initially applied to carnations, which were easier to work with, and eventuated in the commercial release of its range of "blue" and long-life varieties. A return to pursuit of the original agenda of the blue rose has since linked Florigene's activities into CSIRO research and its RNAi (RNA interference or "gene

silencing”) technology, a new and important approach in the field of genetic modification.

Since the takeover by Suntory, Florigene’s research has also expanded sideways into colour modifications of torenias, as has been outlined in the case study. It is to be presumed from the large range involved (nine varieties) and its application of previously developed technology that this research has a more directly commercial purpose.

The application of biotechnological skills and facilities to the development of novel flower colours might seem a frivolous or unnecessary use of scientific resources that could otherwise be devoted to more socially useful work. However the freedom to do this is inherent to the political and economic values now central to western life. According to these values, any expansion of the field of human knowledge is positive and may ultimately be instrumental to the betterment of the human condition. It seems very likely that Florigene’s work, which has placed it at the forefront of its field, will yield significant and valuable economic activity for Victoria over the longer term as the technology matures and is incorporated into mainstream floriculture. Their work has considerably extended the boundaries of understanding of these fields of genetics and could possibly have implications for the future development of more conventionally valued technologies such as food and pharmaceutical production.

Had the incentive to pursue these lines of research been removed by the imposition of State precautionary bans in the 1980s and 1990s, it is quite clear that the work would have been lost to Australia and carried out by other researchers in other nations, who were already investigating pigmentation. Australian investors would obviously not have supported long-term, expensive genetic research under moratorium conditions. The precautionary approach more latterly taken by the States, including Victoria, must have been a considerable disincentive for investment in biotechnology and in particular, a source of considerable hardship for Florigene.

The social consequences of scientifically based regulation of GM carnations

The most conspicuous quality of the social attitude to GM carnations is probably the almost complete absence of political controversy. This can no doubt be largely attributed to the facts that because carnations are not regarded as an edible plant in Australia and crops are minuscule, the assurances of science that they pose no biosafety threat are more readily accepted. While the prospect of the cultivation on farms of GM canola, GM poppies and, to some extent, GM cotton have aroused strong emotional reactions and led to years of enquiry and indecision, GM blue carnations have managed to slip into suburban gardens virtually unnoticed.

In respect of resolving political conflict over GM technology, the strong perceptual differentiation between the carnation and major crop plants seems to be a positive development from most points of view. Because the blue carnation is removed from the glare of controversy, it appears that its environmental credentials may be demonstrated through experience and gradual introduction with general acceptance of the outcome.

The distance that exists between GM carnations and the emotional area of food, and their limited scale of production also renders these varieties a fairly unattractive political target for anti-GM campaigners. Active opposition could even be counterproductive. Although quite erroneous scientifically, the perception appears to exist that a colour variant of a small and decorative flower, appealing to brides and to grandmothers with green fingers can pose no environmental threat. GM canola, on the other hand, a ubiquitous, vivid-yellow-flowered crop, grown in vast paddocks and producing oil for human consumption, is more easily characterised as a threat. These perceptions of the two crops have carried through to their regulation in Victoria, the development of GM carnations proceeding unconstrained through the canola moratorium years.

The aspirational origins of these two GM crops and the nature of the interests associated with their development and production also provide a striking contrast that is informative of the politics surrounding GM technology.

Canola is an agricultural commodity, which means that it is typically grown to a standard and is produced, bought and sold in large volumes on a competitive basis in an open market. Like most commodities, it is increasingly produced in a system that remains profitable for large concerns only. Carnations, on the other hand, are typically grown by small horticultural enterprises, producing small volumes of high value crops that are usually retailed by independent, probably family owned outlets.

GM canola lines have been patented by large and generally unpopular TNCs, that are frequently seen to be powerful, heartless and greedy, whereas the blue carnation was developed by a small, local company, perceived to be constantly struggling against bankruptcy in pursuit of a simple, if not childish dream. The publicly known story of Florigene is a fairytale narrative of a small and unlikely corporate hero taking the biotechnological field and prevailing against monster corporations that would stamp it out of existence. Since in cold political terms, attacks on small and vulnerable players in a small and vulnerable industry is a poor option compared to attacks on large, corporate players in a multi-billion dollar industry, the blue carnation has apparently escaped direct anti-GM pressure.

The GM carnation industry now appears to be quietly flourishing in Australia, having established a track record of problem free existence in domestic garden environments and commercial floriculture. Since they are

now available to the public as both a cut flower and a domestic plant, it seems natural that many if not most people encountering them will have accepted them as a part of everyday life long before considering their genetic origin. There is no suggestion of any significant commercial or community opposition to these varieties.

A 2006 decision by the OGTR to allow Florigene to conduct greenhouse trials of GM roses at Silvan in the Dandenongs, near Melbourne, raised a complaint from a local council, which had passed a motion declaring that no GMOs could be grown within its jurisdiction. The council's ire was voiced by a local councillor and publicised in a community newspaper. However, residents were apparently untroubled by the presence of the rose and neighbouring rose nurseries shrugged off the issue:

Newstead Rose Nursery owner Karen Nieuwestegg said although she didn't know much about the trial ... if [it] ... could produce a blue rose it would be "fantastic" and that it would also be good for the rose industry in the hills. "If we (Australian rose industry) can produce and sell the first blue rose in the world, it would be quite incredible" ... Ms Nieuwestegg said finding the perfect blue rose had been a desire of rose growers for centuries.

Cathy Roberts from Ladybird Roses has also questioned why the council was opposed to the trial. ... Talking about the council's concerns for cross-species contamination, Ms Roberts said there was no floriculture threat to the shire as the trial of the blue rose is in a controlled environment with the flowers being removed before setting seed. "We have no community outrage at all. We have had great interest with the general public wanting to know where they would be able to get hold of the world's first blue rose," she said. (Martin, 2006).

The salient point for this analysis is that regulation on the basis of scientific

understanding has allowed the risks of GM carnations to be assessed on their demonstrable merits. In the absence of evidence to the contrary, the technology appears to have been accepted by both industry members and the public as quite safe. It is unlikely that such effective resolution of the issues would have occurred in the more hostile climate of precaution.

Genetically Modified Poppy

The direct consequences of the precautionary regulation of GM poppies

The most direct consequence of the Tasmanian ban on GM crops is that GM poppies are not grown, although GM trials have been conducted in the past by both the major alkaloid manufacturers. This also means that conventional poppies, involving conventional production techniques, continue to be grown. However, since Australian GM poppy research has virtually ceased as a consequence of the Tasmanian moratorium (Fist, 2008), the nature of potential alternatives to conventional varieties remains uncertain.

Dr Tony Fist, Manager of Agricultural Research for Tasmanian Alkaloids and breeder of the thebaine yielding “top1” poppy, considers that the need for GM technology in the industry is pressing and that GM poppies are likely to become the international norm over the next quarter century or so (Fist, 2006). Apart from yield enhancement, he identified herbicide and disease resistance, among other traits, as being potentially useful to the poppy

industry. These modifications, already applied to cotton and canola, could reduce chemical use in poppy crops.

Effects on the soil

Although no identified positive or negative consequences for soil health ensue from the Tasmanian ban on GM varieties, the general premise that chemical dependent agriculture has passed its zenith suggests that the potential life span of conventional agricultural systems is limited. While this is not yet a significant issue in poppy production, over the medium term, the attraction of GM technology seems likely to increase through agrichemical reductions.

Effects on the water

A similar situation may be considered to be applicable to water and waterways. Without GM technology, the prospects for reductions in chemical use are limited to conventional approaches.

Effects on the open or “air” environment

As a consequence of the moratorium on GM crops in Tasmania, there is no possibility of novel genes being disseminated into the open environment from GM poppy crops. Since no such hazard from GM poppies has been demonstrated, this is not a positive outcome of the GM ban. If Tasmanian policy were reversed, the investigation of such risks would be the concern of

the OGTR. These concerns have nonetheless swayed public perception in relation to GM poppies²¹.

²¹ A contentious potential complication of GM poppy technology is that it could lead to the adventitious presence of significant levels of GM pollen in honey (Fist, 2006). This matter was given some attention by the Tasmanian Government's Expert Group on Gene Technology (EGGT, 2001:12-19), which considered it in its investigation of gene flow as a part of a comprehensive assessment of the risks posed by GM poppies (EGGT 2001). The question of GM pollen and honey has also been addressed by public GM canola enquiries such as the ACIL Tasman/Farm Horizons report. A closely related concern is that viable GM pollen movement could affect weeds or native plants.

Any distribution of poppy genes as pollen is hampered from the outset because poppy pollen is not physically well equipped for transport and survival in the open environment. According to poppy researchers, the pollen of poppies is fragile, heavy and sticky, so movement from its parent plant in a viable state is severely restricted. This is such a limiting factor that self-pollination of poppies predominates, even within the confines of densely planted crops (Chitty et al 2003: 1056; EGGT, 2001: 14). Chitty et al found that "very little pollen is effective beyond a metre" and that under open field conditions "transgenic poppy pollen does not pollinate compatible poppies more than a few metres away" (Chitty et al 2003: 1056). Accordingly, pollen transport by bees could be expected to be of low viability.

EGGT concluded, for a number of reasons that are well explained, that the likelihood of novel genetic material being transferred to native flora or to weed populations is remote (EGGT, 2001:13-14). Furthermore, since all opium poppy production is subject to strict management procedures and supervision in order to prevent opiate diversion, the likelihood of the transfer of novel genes to other crops or to weeds is minimal and (as long as poppies remain a controlled crop) this avenue is intrinsically manageable.

With respect to the presence of GM pollen in honey, the 2004 ACIL Tasman/Farm Horizons report on GM canola prepared for the Victorian Government, concluded that the matter was effectively dealt with by existing Australian food standards. The maximum adventitious level of GM material permitted in honey is 1% w/w, but total pollen rarely amounts to more than a small fraction of this percentage (ACIL Tasman, 2004: 43-44) so little difficulty would be anticipated to normally be involved in the containment of unintentional GM content.

The economic consequences of the precautionary regulation of GM poppies

Enterprise Level

While to date there are no examples of commercial GM poppy cultivation to compare with Tasmania's existing conventionally bred varieties, the economic advantages associated with such potential GM traits as increased alkaloid content, herbicide resistance or disease resistance are intrinsic to the concept of varietal improvement. It is therefore virtually inevitable that, at some point, the absence of GM varieties will put Tasmanian poppy growers at an economic disadvantage. Until a commercially viable GM alternative appears, it is not possible to quantify this disadvantage. Dr Fist considers that so far, there is no significant disadvantage (Fist, 2008). However, as time passes, the likelihood of a competitor adopting GM technology increases.

This report suggested some specific strategies to minimise the opportunities for GM material to find its way into honey, which might be applicable to poppies. These were (a) the separation of GM and non-GM crops, (b) "using GM plants where the transgene is not expressed in pollen, or the transgene occurs only in chloroplasts, or where pollen or flower formation is blocked" and (c) the removal of pollen from honey by filtration (ACIL Tasman, 2004:44). Coordination of hive placements so that bees do not have access to flowering poppies is another easily implemented means of minimising the presence of poppy pollen in honey.

It can reasonably be concluded from the above that while the current GM ban ensures that gene flow cannot occur at all, the risks attached to the alternative regulatory regime are limited and manageable, so the direct benefit delivered by the moratorium is in this regard minimal.

Community Level

As has been mentioned in the case study, the reversal of fortunes suffered by the poppy sector in recent years is generally attributed to global oversupply. It is clear from the production figures that have been presented that Tasmanian production has declined very seriously since the peak years around the year 2000. Given Dr Fist's assessment that growers have not so far been disadvantaged, the possibility that the GM moratorium has exacerbated this decline seems remote.

The ban on GM poppies, however, is a consequence of a generic ban on GM crops in Tasmania, imposed on the basis of a suggested need to protect food markets from any association with GM technology. This dependently locks the future prospects of poppy growers into the preferences and prospects of the food production sector, especially fresh fruit and vegetable producers. It follows that the fortunes of the alkaloid industry need to be interpreted in the light of the economic consequences of Tasmania's GM free status on these other primary industry sectors. Whether a precautionary or scientific regulatory system ultimately prevails must ultimately rely heavily upon the comparative economic consequences of these systems for primary industry as a whole.

Trade in products that are supposed to depend for their future on a GM free status has not generally increased since the introduction of the moratorium,

even though protection and enhancement of export markets has continually been advanced as the main justification for it²². Mr. Buzz Green, an agricultural scientist from the main horticultural region of Tasmania, considers the moratorium to have been damaging to Tasmanian agriculture as a whole. Interviewed during the course of this research, he said of the Tasmanian ban on GM crops, “There is no evidence that we have benefitted from the moratoriums²³, but many people have suffered” (Green, 2006).

²² Although an export market with a similar demographic character to the organic market could possibly develop and persist for some decades, without supportive evidence, the assumption that this will occur and that Tasmania’s agricultural policy should be adjusted accordingly is largely speculative. The case study has shown that the fruit and vegetable producers who might benefit from Tasmania’s GM free status presently amount to a small percentage of the total and unless demand is stimulated by anti-GM sentiment, there is no reason for this market to grow. It is probably more realistic to expect that over time it will shrink as people become more comfortable with the technology. A further difficulty for the GM free strategy is that the productivity differential between GM and non-GM systems is likely to become more pronounced as the technology advances.

²³ Official figures support the view that no benefit has flowed from the moratorium. They show that the introduction of the Tasmanian GM ban does not correlate with any significant trend towards growth in demand for Tasmanian fruit and vegetables. Neither has there been any public indication of the existence of any significant and reliable markets demanding GM free fruit and vegetables, either with or without the necessary compensatory premium. As the case study has shown, the long decline in demand for Tasmanian potatoes, the traditional vegetable industry staple, has actually worsened sharply in recent years. This decline has been linked to the unrealistic expectations of the Tasmanian industry, which has been reluctant to make the difficult adjustments necessary for it to operate competitively in a rapidly globalising market (Barnes, 2005).

Exports of apples and pears, once the flagship products of Tasmania, have fallen in a similar fashion to potatoes, but with an even more pronounced long-term decline. Exports have collapsed further since the GM moratoriums were implemented and as has been pointed out

Simple analysis suggests that the absence of a positive market response to the moratorium is unsurprising. Nations that have already adopted GM crops are in possession of much of the world's arable areas, having jurisdiction over almost the entire Americas, most of Asia (India, China and the Philippines), the Australian continent as well as parts of Africa and a significant portion of Western Europe (ASAAA, 2007). Global adoption of GM crops "has consistently conformed to a straight, upwardly inclined line of increase²⁴" (Green, 2006) and it follows that trade in and consumption of GM produce must follow the same trajectory.

In 2006, more than five years after GM bans began, Buzz Green described the Tasmanian vegetable industry as being "in crisis" as a consequence of competition from cheaper imports (Green, 2006). In spite of claims that a GM-free image would benefit Tasmania's primary producers, Green's view is that it has been damaging, because the record shows that product origin and history is of little importance to buyers in comparison with price.

... in respect of market perception, the market is saying that it will buy

in the case study, the value of apple and pear exports has been eroded to a token few million dollars. Buzz Green observed that, "The moratorium represents an ideological position and offers no tangible benefit. Apples have really struggled through most of the moratorium years. They have gained no markets through the moratorium" (Green, 2006).

²⁴ Growth of 12% in 2007 took the global total of GM crops to over 114 million hectares (285 million acres) spread over 23 countries (ASAAA, 2007). Unless some kind of unforeseen catastrophe ensues, adoption and acceptance of GM products seems bound to continue to the point of complete saturation of mainstream agriculture.

Chinese vegetables even though China is a major grower of GM crops. Also, Chinese agriculture is not sustainable in our terms. It uses questionable fertilizers and chemicals, there are microbial residue issues and it employs a very different regime of labour laws. (Green, 2006).

Green also suggested that the tactic of extending the GM ban to non-food crops as a marketing device is likely to be counter-productive because it conflicts with scientific fact and existing market realities.

There are some Japanese clients who have suggested that any GM crops at all would threaten Tasmania's position, but I do not believe that to be the case because Japan quite happily imports food from the US and China where GM technology is accepted. No doubt there are opportunities for "total GM-free" crops, but the science would say that it is not based upon understanding. How could GM poppy pollen affect apples? If GM is to be banned on this basis, so should many other things. We know that oleanders are poisonous, so if GM poppy pollen involves a risk, what about oleander pollen? There is no scientific reason why GM poppies should not be grown in the same field as organic carrots, but those wishing to stop GM *make* a problem of it. It is true that GM crops could damage *some* trade with *some* individuals, but excluding GM has damaged opportunities for many growers here and buyers elsewhere. (Green, 2006).

Likely economic losses to Tasmanian primary industry from the GM moratorium are not confined to its failure to generate revenue. Green referred one viable and significant GM venture that was closed down at an advanced stage of development, so biotechnology investors are unlikely to consider Tasmania as a sound prospect in the future²⁵.

²⁵ In the context of the Tasmanian DPI conducting GM potato and canola trials and the poppy industry "exploring the technology" during the 1990s, Buzz Green's company Serv-Ag became interested in a proposal to establish a commercially based GM, R&D capability in the State as a resource for Northern Hemisphere agriculture (Green, 2006).

National Level

Because the poppy industry is confined to Tasmania, and since the industry is relatively small, it has limited national economic significance, but as an export-focussed industry with the capacity for growth, its future value is

The company got involved with northern hemisphere companies interested in screening GM canola seed lines in their off-season ... Participation in the canola trials seemed to be a great opportunity to secure a foothold in an emerging technology. ... There was an immediate potential of \$10M in seed production contracts with the likelihood of significant growth and the development of other things. Tasmania was considered to be a near ideal location, with a reliable climate and appropriate infrastructure so that consistent quality of product was possible. Based on our performance there was strong interest in development here. Discussions were also under way with a number of US companies concerning “nutriceuticals” – small scale crops modified for nutritional benefits ... These high-value, intensively produced crops were a very good fit for Tasmania. We could offer good control, having very well qualified people backed by research and excellent climatic and other growing conditions. (Green, 2006)

Green described how this “strategic opportunity”, which progressed to the stage of “developing a business network in the Northern Hemisphere” and growing “commercial scale” trials was killed off after “the Greens got wind of it and political difficulties arose” (Green, 2006).

There was a massive flow of misinformation that generally raised people’s concerns. Serv-Ag was targeted as a company, so we felt the need to get up and explain what was going on to people. We thought that someone from the science community should stand up and talk about it. We thought there would be support, but we were wrong. We were savaged. Extremist elements disrupted our meetings. They seemed to feel that they had the ethical high ground. It was not as if we were expressing an opinion, I was not going to stand up and talk about anything I did not know about. (Green, 2006).

This opportunity was ultimately taken up in Chile, which in 2007 produced “over 25,000 hectares of commercial biotech crops for seed export” (ISAAA, 2007).

potentially much greater. The national impact of precautionary regulation of GM poppies is presently minimal, but this cost could grow and at worst the industry could be lost to competitor nations.

The conceptual consequences of the precautionary regulation of GM poppies

Dr Tony Fist of Tasmanian Alkaloids expressed the view that “the potential differences between a GM-based industry and a non-GM approach are large” (Fist, 2008) and if he is correct, the long-term impact of precautionary regulation on the poppy industry is also likely to be large. The economic and scientific potential of the industry is consequently very policy dependent. The fluidity of perceptions and expectations is already evident in changes to research programs and falling industry expectations are reflected in the gradual closing down of GM poppy research in Australia.

In 2006, Dr Fist said of the GM moratorium that the “main effect emerging is a loss of confidence in the long term. If commercial applications are unlikely, it makes it harder to generate enthusiasm for research proposals within the company” (Fist, 2006). Just two years later, when asked a similar question, he said that the direction of research had swung back to “conventional breeding”.

Our project with the CSIRO has been wound up and the work we are doing at present is basically tying up loose ends from that project. We have been considering some new GM projects, but so far haven't started any. This is mainly because of the potential difficulties in commercialising the technology,

which is partly due to the moratorium and partly the negative image of GM in the community (which has been reinforced by the government attitude). (Fist, 2008).

While conceding that dramatic advances in alkaloid content had not been achieved so far, he emphasised the long lead times involved in biotechnology and the importance of consistency of support for the work. Had investment been ongoing, he would have expected to achieve “50-100% improvement” in alkaloid content “in the next 5-10 years” and commercial release around 2018 (Fist, 2008). Although research to date has “only just scratched the surface” of poppy potential, given “the current lack of support from the government” he did not expect that any of the alkaloid concerns would be prepared to fund it any further²⁶ (Fist, 2008).

²⁶ Research is, however proceeding successfully in other parts of the world, a development that puts the industry and government on notice to deal with the issue of GM technology.

“...a Canadian researcher, Peter Facchini has just published a paper demonstrating that he has produced a GM herbicide resistant poppy. It is very similar to work that we did about 10 years ago with CSIRO. The paper acknowledges support provided by the French poppy company Sanofi. This suggests that the lead we had in GM poppy research is being eroded”. (Fist, 2008)

Facchini’s paper (Facchini, Loukanina and Blanche, 2008:719-727) makes it quite clear that serious, successful and supported investigation of the commercial applications of gene technology in poppies is being pursued by competitor alkaloid industries. A non-GM Tasmanian poppy industry may have an immediate future, but given the scale of potential productivity gains, it must be of limited and diminishing potential. Conventional poppies are bound to quickly become outmoded and uneconomic in the agronomic context of stacked GM varieties with multiple resistances and much higher alkaloid yields. It would seem to be a given that a choice between GM-free status and a Tasmanian poppy industry will soon be forced upon the Tasmanian Government.

The social consequences of the precautionary regulation of GM poppies

The suspension of corporate funding for GM poppy research as a consequence of Tasmania's declared "GM-free" status, means that GM technology is currently excluded as a possible means of industry improvement. The further consequences of this situation are (a) that GM is at risk of becoming established in the public mind as an unacceptable and/or dangerous technology and (b) the debate is showing no signs of being satisfactorily resolved.

(a) Without a clearly articulated justifying logic - such as demonstrable hazard or genuine ongoing enquiry - the deliberate or incidental shutting down of research, development and use of GM technology is in conflict with social values taken for granted in the west since The Enlightenment. Unless it is supported by good evidence, the regulatory action of implementing precautionary bans can only be interpreted as the embracement of a soft political option. In time, the quality of the decision will be revealed by the long-term performance of GM crops and even if in the meantime the community is persuaded to support it, the economic effects of the policy and confusion over its logic will be felt in the community. The political pitfalls of neglecting the pursuit of understanding are obvious, but complaints that there has been no serious attempt to investigate the entailments of either accepting or rejecting GM technology are common²⁷.

²⁷ Buzz Green recalled that the government originally undertook to investigate and settle

The Tasmanian Government does not acknowledge that any such responsibility exists, however. In an interview about GM policy conducted for this research, Cindy Hanson, Senior Policy Analyst for the Tasmanian Department of Primary Industry, Water and Environment said, “The current approach is intended to allow independent exploration of the options. The

these matters in accordance with generally acceptable principles.

“It was understood that it [the State Government] would research market dynamics and the likely consequences of GM adoption and GM free strategies. But they have not done these things, so it seems logical to conclude that the moratorium is political”. (Green, 2006)

Tony Fist concurred: “When the moratorium was declared, a commitment was made to research the various issues and options provoked by GM technology, but little appears to have been done” (Fist, 2006). The claims of both these sources concur with the implications made in published policy position papers (DPIWE, 2001: 24; DPIWE, 2003: 5-6) although the actual written undertakings are ambiguously framed.

Both of these sources also commented on the conspicuous lack of government activity in support of the moratorium. Buzz Green:

“There has been no related program of promotion of Tasmanian produce and no attempt to quantify what is happening or might happen in the markets. The current policy is nominally GM free, but it is not being applied strategically”. (Green, 2006)

Tony Fist:

“The prevailing logic is that conventional breeding is better, but the Government is not doing anything to protect these values. New Zealand is very active in this field, producing a wide range of new varieties, such as red-fleshed apples and kiwi fruit, whereas Australia is importing broccoli from China. There are no fruit or vegetable plant breeders working in Tasmania. The only public sector plant breeders work with barley ... When the moratorium was declared, a commitment was made to research the various issues and options provoked by GM technology but little appears to have been done”. (Fist, 2006)

independent interests should use the moratorium as an opportunity to investigate the possibilities”²⁸ (Hanson, 2006).

In respect of the absence of price premiums for non-GM produce, Ms Hanson said that a premium “may appear with time” (Hanson, 2006). In respect of industry frustration, she said that there “have been no approaches or complaints by industry in regard to uncertainty” (Hanson, 2006). She also indicated that the demands of the GM free policy would take priority over the needs of the poppy industry for GM technology, saying, “Tasmania is not the only place in the world where commercial poppy cultivation is possible” (Hanson, 2006).

²⁸ When directly asked about the Government’s own record of research to resolve uncertainty about the future, her reply was:

“The Government is providing clarity through implementation of policy, the ongoing process of review, the legislation, which supports the moratorium and through the signals it is sending to industry about government policy.

The Government has also imposed import restrictions, such as those relating to GM canola.

...As far as market research is concerned, a differentiation-based market advantage is not likely to appear before GM adoption becomes widespread. It is anticipated that Tasmania will be one of the few places that will be able to successfully implement a GM free agricultural regime”.

When pressed about the empirical basis of the supposition that a reliable GM-free market exists, she said “There are strong market signals to support this view”, but would not elaborate, suggesting that the sources of this information were too sensitive to divulge (Hanson, 2006).

(b) Tasmanian GM policy has been marked by overt indecision for the better part of ten years. The case study has instanced two recent high quality government publications, one endorsed by the minister responsible for primary industry and the other by the premier, that advocate completely contradictory approaches to GM technology. The social impact of this indecision parallels the economic insofar as uncertainty and inaction appear to have become entrenched. The prospects for any change seem poor, as the alternative government has not noticeably applied pressure for clearer policy and shows every sign of following a similarly tepid policy path itself.

The Tasmanian Liberal Party supports the caution with which the Labor Government has approached the GM issue, but claims a difference of approach in respect of the specific policy articulated by Ms Hanson. Mr Jeremy Rockliff MHA, the shadow primary industry minister, considers that the weak point of the current Tasmanian position is the perception that GM policy is essentially about marketing. He asserted that the approach would change under a Liberal administration and that “it is necessary to learn more”.

It is necessary to determine whether sustainable markets actually exist and what the opportunity costs would be likely to be. ...[if] damage to ... the poppy or dairy industry was likely to amount to tens of millions of dollars, all the options ... would need to be very closely examined. ... The demands would be ranked on economics – on the existing value of the industries to Tasmania and projections of future benefits. The present emphasis is solely on markets, but there could be a significant social cost in *not* going down the GM path. There would be no point in driving an area such as the far North West Coast into poverty for ideological reasons. (Rockliff, 2006).

If the GM-free market issue was to be thoroughly investigated, it might, indeed, lead to political emphasis of the realities of economics rather than the conjectures of marketing. However, the lack of opposition activity in this field over the period of the moratorium and its clear avoidance of strong policy distinction from the government suggest that there is little genuine political interest in resolving the GM poppy issue in Tasmania.

Summary of Main Analytical Points

This analysis has established and compared the outcomes of alternative regulatory approaches to four GM crops, on the basis of four criteria. The results are clear-cut and unambiguous in most of the sixteen resulting analytical items (illustrated in Table 8.7, below). Comparison between the overall outcomes of the two regulatory systems is equally decisive, as is comparison of the actual outcome for any crop with the likely outcome under the alternative arrangements.

In the case of GM cotton, the science based regulatory approach taken at the time of its introduction led to a dramatic reduction in chemical applications, which had very desirable environmental, economic, agronomic and social effects. Long-established division and anger in the community over cotton growing practices has vanished and cotton R&D has moved on to consolidate the gains and address new challenges.

Table 8.7.

GM CROP	REGULATORY INFLUENCES			
	Direct	Economic	Conceptual	Social
Cotton (Science-based)	Soil Bt: neutral Chem: +ve Water Bt: neutral Chem: +ve Air Bt: neutral Chem: +ve	Grower +ve Community +ve Nation +ve	The research agenda has moved on to new areas of need.	The public image of the cotton industry has been transformed; community tensions have been resolved.
Canola (Precautionary)	Soil Physical: -ve Chem: -ve Water Chem: -ve Air Neutral	Grower -ve Community -ve Nation -ve	Research program has been set back by some years; research sector has lost basic resources.	Political tensions have remained. Social concerns are unresolved.
Carnation (Science based)	Soil Neutral Water Neutral Air Neutral	Grower +ve Community +ve Nation Neutral	Research has progressed as far and fast as the market and resources have allowed.	Direct political difficulties have been minimal. Carnations have found acceptance in the market.
Poppy (Precautionary)	Soil Neutral Water Neutral Air Neutral	Grower Neutral Community Neutral Nation Neutral	GM poppy research has been wound down in Australia. The outlook is discouraging for the industry.	Tasmania has adopted a GM free stance. It has provoked bitter debate.

Tabular summary of the analysis

The precautionary regulation of GM canola in the canola-growing States has (until the 2008 season in NSW and Victoria only) completely prevented its commercial adoption in Australia. This stricture has compromised the

volume and quality of the national crop, while entailing higher inputs, the application of large amounts of environmentally hazardous chemicals and less sustainable farming systems. It has adversely affected Australia's canola research capability.

Florigene, a small, local company now owned by a Japanese brewing concern developed GM blue carnations in Victoria. It has also bred a blue rose and over a number of years has steadily extended its range of GM varieties. GM flower breeding and propagation now comprises a small but apparently healthy Victorian industry. Like cotton in NSW and Queensland, GM carnations were regulated from the early 1990s on a scientific footing. With an expanding global supply network now established, secure corporate funding and a strong research base, the future seems assured. GM carnations have been politically uncontroversial.

The precautionary regulation of GM poppies in Tasmania results from the precautionary moratorium on all GM crops in that state. Tasmania's primary production and export performance has deteriorated since the moratorium was introduced. GM poppy research has been curtailed in Tasmania but GM research activity overseas means that the world technological lead that the industry once held is now being eroded.

Chapter 9.

CONCLUSION

This thesis has examined the regulatory value of the Precautionary Principle in respect of its application to GM crops in Australia. It has considered precaution as the conceptual product of a struggle in western democracies to satisfactorily manage the risks associated with rapid advances in science and technology. It has described the difficulty of reconciling the idea of precaution with the principles of scientific analysis and has outlined a research design intended to clarify their respective advantages through the comparison of outcomes. Finally, it has tested two mutually exclusive research hypotheses by analysing the cases of four relevant Australian crops – cotton, canola, opium poppies and carnation - in accordance with a comprehensive framework of outcomes. These hypotheses are:

1. That the precautionary approach to GM crop regulation that has been applied by the Australian States under the Commonwealth Gene Technology Act 2000, is delivering outcomes that are measurably more advantageous to the Australian community than those that arose from the previous science-based approach to regulation.

and

2 That the science-based approach to GM crop regulation applied prior to the Commonwealth Gene Technology Act 2000, delivered measurably more advantageous outcomes to the Australian community than does the current precautionary approach of the Australian States.

In simple terms, the research undertaken has shown that the first hypothesis is not supported, but the second is.

At its most obvious, the analysis has shown that as a regulatory means of dealing with scientific uncertainty about GM technology, the application of precaution has been less effective than a science-based approach with respect to achieving materially advantageous outcomes and settling differences over the technology. In every case-item considered, the effects of precaution on the environment and industry were found to be neutral, repressive or even actively damaging and in no instance was any positive outcome recorded. In both of the agricultural sectors where precautionary bans have been in effect over a long period (canola and poppies), the normal industry improvement activities of research and development have been significantly impaired.

On the basis of these trends, indefinite continuation of precautionary bans could ultimately be expected to threaten the existence of those industries in the States concerned. While such grave eventualities would be very unusual in the Australian political context, it is clear that unless competitors apply similar policies, extended precautionary bans on GM crops must inflict a progressively deepening disadvantage on Australian farmers. Further pressure to accept the technology can be expected to arise from an emerging global food shortage and a new generation of more advanced GM crops in the development pipeline.

The regulatory alternative of significantly informing decisions about GM crops with sound, mainstream scientific findings has, in the cases considered, led to socially acceptable and economically productive outcomes for the industries concerned. Analysis at the case-item level illustrates the depth of this link and explains why more sustainable and competitive industries emerge as a consequence of this regulatory approach. The two industries in which GM varieties have been regulated in accordance with science have been able to take full advantage of current GM technology, but more importantly have maintained healthy levels of research and are now addressing fresh challenges.

These findings do not support the regulatory use of precaution as a solution to the political difficulties associated with GM crop technology. The economic implications, in particular, also cast doubt upon its value as a political or regulatory guide for the management of environmental matters generally, but further work would be necessary to clarify this. Precaution operates merely as a brake and cannot in itself provide the understanding that is necessary for the competent management of emerging technology. This function is the preserve of accountable science, upon which ultimate responsibility for understanding must rest.

Accountable science, which is the hard science of the mainstream west, is the science that operates in the science faculties of Australian universities and in

reputable research organisations such as the CSIRO and the major biotechnology corporations. It is deeply conservative and cautious, and most importantly, is conducted in an open, critical environment. The sciences themselves, as academic disciplines, professions and industries are the only points in the technological train at which precaution can operate without bias, and then only as an integral component of the scientific process. There is no indication in any of the material considered that precautionary oversight of Australian biotechnological science by the States is in any way necessary. Precautionary protection of markets is a different matter because the Commonwealth legislation provides the States with that capacity, but a strategic precautionary ban is a double-edged sword that requires confident mastery of the market if it is to be used to advantage. Although the States have shown no reluctance to apply moratoriums, none has, so far, demonstrated that it has done so to the benefit of its industries. The lifting of the GM canola bans by NSW and Victoria only after their economic price became overwhelmingly evident, is a tacit admission of this realisation.

The analytical findings of this thesis are a product of the inductive approach alluded to in Chapter 1, which has thrown a useful light on the subject matter by comparing the outcomes of the two approaches to regulation. It by no means solves the difficulty of managing GM regulation but it sharply emphasises the imperatives that exist for the custodians of agriculture to fully

understand its markets and to maintain the capability of competitively meeting demand through advanced technology and research.

Further observations and new questions

This analysis has identified economic necessity as a pressing factor affecting the attitudes of farmers, and the cases considered suggest that such economic necessity is vital for mainstream GM technology to gain public acceptance. (The case of GM carnations, although providing useful insights into the evolution of sunrise industries and the subtleties of the politics of technology and precaution, is somewhat unusual and is excluded from this observation as carnations are not an economically important industry.) The marked differences in pragmatic pressure to adopt the three more economically significant crops considered - GM cotton, GM canola and GM poppies - are reflected in the three different stages of political and social acceptance of GM technology that apply to them. Even though there are no sound technological grounds to discriminate between them, and GM opponents cite no such distinction, they can respectively be described as “fully accepted”, “partly accepted” and “not accepted”. These stages of acceptance coincide with the magnitudes of economic pressure to adopt the technology that each is currently imposing on farmers - or put another way, social acceptance of them appears to vary directly in accordance with economic need.

This observation is consistent with the counter-intuitive Meadean understanding of social values as a product, rather than the precursor, of behaviour¹, a concept that Murray Edelman has applied to explain some characteristics of administrative systems. In expounding his own ideas and their basis in Mead's work, Edelman succinctly articulates this idea: "... the ranking of values is the rationalisation of our behaviour: the aftermath of it and not a cause" (Edelman, 1967:50-51).

If economic behaviour is a product of human needs, then, in Mead's terms, needs will determine values. Consequently, when communities respond to specific economic pressures - such as the unsustainability of conventional cotton growing - in fulfillment of fundamental needs, glaring moral inconsistencies, such as existed in NSW until recently between the regulation of GM cotton and GM canola, are bound to arise.

There are other examples. Commercial atomic energy technology has been well established for many years in many countries where circumstances render it an economically practical or necessary proposition. Although science and the record both suggest that high quality reactors offer a more

¹ In "Mind, Self and Society" Mead wrote:

Meaning is thus not to be conceived, fundamentally, as a state of consciousness, or as a set of organised relations existing or subsisting mentally outside the field of experience into which they enter; on the contrary it should be conceived objectively, as having its existence entirely within this field itself. (Mead, 1934:78).

environmentally sustainable energy alternative than fossil fuels, the various risks of adopting nuclear power technology have been avoided in Australia by not utilising it at all. The presence of plentiful and cheap alternatives and relatively low demand for power has meant that the direct incentives to adopt it are slight, yet the strong opposition to nuclear power in the Australian community is generally perceived and portrayed as an important moral stance. The useful but ideologically criticised food irradiation technology has similarly not been taken up in Australia, as the existence of viable alternatives means that it is not essential. However, in the case of atomic medicine, for which there is no alternative, a different order of values prevails, the need for it casts it in a technologically heroic light, even though having it involves the maintenance of an Australian nuclear reactor facility.

Further investigation of the mechanisms operating between the material needs of communities, technological options and social values such as preserving natural environments and species, may enhance understanding of issues currently understood to be about “risk” and pragmatic politics. The discrepancies of regulatory status between GM crops are superficially no more than problems for politicians or administrators, but they may also provide a valuable window into the dynamics of the relationships determining them.

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ACRONYMS

- ABARE: Australian Bureau of Agricultural and Resource Economics.
- ABS: Australian Bureau of Statistics.
- AFAA: AgriFood Awareness Australia.
- AIDS: Acquired Immuno-Deficiency Syndrome.
- API: Active Pharmaceutical Ingredient.
- APVMA: Australian Pesticides and Veterinary Medicines Authority.
- AZT: Azidothymidine
- BINAS: Biosafety Information Network and Advisory Service (UN).
- BMP: Best Management Practice.
- BSE: Bovine Spongiform Encephalitis.
- Bt: *Bacillus thuringiensis*.
- CCC: Canola Council of Canada.
- CJD: Creutzfeldt-Jakob Disease.
- CoOL: Country of Origin Labelling.
- CPS: Concentrate of Poppy Straw.
- CRA: Comparative Risk Assessment.
- CCC CRC: Cotton Catchment Communities Cooperative Research Centre.
- CRDC: Cotton Research and Development Corporation.
- CSD: Cotton Seed Distributors.
- DAFF: Department of Agriculture Fisheries and Forestry (Aus).
- DDT: Dichloro-Diphenyl-Trichloroethane.

DEFRA: Department for environment Food and Rural Affairs (UK).

DPEM: Department of Police and Emergency Management (Tas).

DPI: Department of Primary Industry (various Australian States).

DPIW: Department of Primary Industries Water (Tas – since June 2006).

DPIWE: Department of Primary Industries Water and Environment (Tas – prior to June 2006).

DPPS: Department of Police and Public Safety (Tas).

EGGT: Experts' Group on Gene Technology (Tas).

EPA: Environmental Protection Agency (US).

ESD: Economically Sustainable Development.

EU: European Union.

FAO: Food and Agriculture Organisation (UN).

GM: Genetically Modified; Genetic Modification.

GMAC: (obsolete) Gene Manipulation Advisory Committee (Aus).

GMO: Genetically Modified Organism.

GRDC: Grains Research and Development Corporation.

HCWA: Heritage Council of Western Australia.

HIV: Human Immuno-deficiency Virus.

INCB: International Narcotics Control Board (UN).

IPM: Integrated Pest Management.

IRIS: Infrastructure and Resource Information Service (Tas).

ITC: Isothiocyanates.

JSCGT: Joint Select Committee on Gene Technology (Tas).

LWA: Land and Water Management Australia.

MHA: Member of the House of Assembly (Tas).

ML: Megalitre (one million litres)

OGTR: Office of the Gene Technology Regulator (Aus).

PACB: Poppy Advisory and Control Board (Tas).

R&D: Research and Development.

RMP: Resistance Management Plan.

RMS: Resistance Management Strategy.

TDED: Tasmanian Department of Economic Development.

TFES: Tasmanian Freight Equalisation Scheme.

TFGA: Tasmanian Farmers and Graziers Association.

TT: Triazine tolerant.

UK: United Kingdom.

UN: United Nations.

UNODC: United Nations Office on Drugs and Crime.

USA: United States of America.

GLOSSARY

alkaloid A class of over 12,000 plant-derived, basic, nitrogenous, bitter, organic compounds, which includes caffeine, atropine, cocaine, morphine, nicotine, quinine and strychnine. They are highly reactive and affect biological systems at low dosages. The opium poppy, *Papaver somniferum*, produces over twenty alkaloids, morphine being both the most abundant and of principal economic importance. Alkaloids are recognisable by their invariable ‘-ine’ suffix. In rare cases, such as the poison-dart frog, they can have an animal origin.

API Active pharmaceutical ingredient. In this context, poppy-derived alkaloids.

BAR A gene of bacterial origin conferring resistance to glufosinate.

biofumigation The suppression of pests and pathogens in the soil through the activity of compounds of biological origin, especially isothiocyanates released through the hydrolysis of glucosinolates produced by agricultural crops such as canola.

biotechnology Technology fundamentally involving and utilising living organisms, and biological processes.

biosafety Level of physical risk attached to any technology with respect to all life forms – that is in both human and wider environments. The main responsibility of the OGTR is to assess biosafety.

biosynthesis The manufacture of organic compounds by a living organism.

biosynthetic pathway The sequence of events or steps involved in biosynthesis.

canola An oil-crop derived from rapeseed having the characteristic of reduced glucosinolate and erucic acid content. The word “canola” is an acronym of **CAN**adian **OIL** **L**ow **A**cid.

clone (1) A non-sexually produced organism that is genetically identical to its parent. (2) the action of generating a recombinant (or synthetic) *DNA* sequence.

CP4 EPSPS A gene of bacterial origin conferring resistance to glyphosate.

CPS Concentrate of poppy straw. A saleable, narcotic raw material.

Cry1 ac and Cry2 Ab Genes used in GM crop technology that originate in the soil bacterium, *Bacillus thuringiensis* and provide resistance to attack from certain insect pests.

cultivar An identifiable and deliberately propagated variety or strain of a plant species

diapause A state of suspended activity and metabolism that may occur at any stage of the insect life cycle, and which enables individuals to survive unfavourable conditions. Its onset and termination are usually triggered by stimuli such as temperature or day length.

DNA (deoxyribonucleic acid) The fundamental, molecular material of genes.

endosulfan An insecticide associated with severe environmental damage that was widely used on cotton prior to the availability of GM varieties.

erucic acid A long chain fatty acid present at high levels (around 40%) in rapeseed oil and constituting a health risk. Canola oil has dramatically reduced erucic acid content (around 0.5%).

gene The basic unit of genetic (inheritable) information. A segment of a chromosome.

gene flow The movement of genes from one population to another. May be horizontal or vertical.

genetic engineering (GE) See genetic modification.

genetic modification (GM) The deliberate and usually specific, technological alteration of the genetic structure of an organism.

genetically modified (GM) Descriptive term pertaining to genetic modification.

genetically modified organism (GMO) An organism (or its descendant) which has had its genetic makeup technologically altered.

genome The complete genetic complement of an organism or species. Often used as a synonym for genotype.

genotype The particular combination of genes which constitutes an individual, genetically identifiable organism, or the genetic description of a particular cultivar of plant.

germplasm Genetic raw material – seeds, tissue etc that constitute genetic resources. Breeders use the term to refer to their varietal bases and breeding lines.

glufosinate-ammonium (usually referred to as “glufosinate”) The broad spectrum herbicide marketed as “Liberty” and “Basta” that is used in the Bayer corporation’s GM herbicide resistance program.

glucosinolates A class of thioglucosides characteristic of the Brassicaceae family that give *Brassica* vegetables their strong, biting flavours and which are accumulated in the seed. They have been substantially reduced in canola varieties through selective breeding programs.

glyphosate The broad spectrum herbicide marketed as “Roundup” that is used in the Monsanto corporation’s GM herbicide resistance program.

goxv247 A gene of bacterial origin conferring resistance to glyphosate.

horizontal gene flow movement of genetic material between individual organisms by means other than normal reproductive avenues.

hectare (ha) Metric unit of land area consisting of 10,000 square metres and approximately equivalent to 2.5 acres.

Helicoverpa armigera The cotton bollworm. A serious, mid to late season insect pest of cotton, controllable with GM technology.

Helicoverpa punctigera The native budworm. A serious, early season insect pest of cotton, controllable with GM technology.

herbicide A plant poison. “Knockdown” herbicides kill established plants. “Pre-emergent” or “residual” herbicides become fixed in the surface layers of the soil and kill seedlings as they emerge. “Broad spectrum” herbicides kill plants indiscriminately. “Selective” herbicides kill only particular types, such as grasses or broadleafed plants.

imidazolinones A group of herbicides used in conjunction with imidazolinone resistant canola varieties (IT canolas).

insecticide An insect poison.

kg/ha Kilograms per hectare

methylation The chemical process of replacing a hydrogen atom with a methyl group.

morphine The alkaloid at the end of the biosynthetic pathway in the opium poppy which is used in severe pain relief as well as in the manufacture of pain-killing drugs such as codeine.

mutagen a physical or chemical agent able to trigger mutations.

mutagenesis A plant breeding technique involving the use of a mutagen to produce mutated plants which can then be screened for desirable characteristics.

mutation a naturally occurring change in the DNA of a cell as a result of a chromosome breakage, chemical modification or other unusual event which results in a variant form of a gene.

narcotic A class of drug that blunts the senses, relieves pain and induces sleep.

Norman A morphine-free strain of opium poppy developed by Tasmanian Alkaloids in the 1990s in which alkaloid biosynthesis ends at the thebaine stage. It yields only thebaine and oripavine, another useful alkaloid. This characteristic is due to a single recessive gene.

OGTR Office of the Gene Technology Regulator, the body responsible for the licensing of GMOs in Australia.

oripavine An alkaloid synthesised in quantity only in the Norman strain of poppy. It can be methylated to produce thebaine.

PAT A gene of bacterial origin conferring resistance to glufosinate.

pathogen a disease-causing organism.

pesticides strictly a generic term for substances toxic to pests but often misapplied as a synonym for insecticides.

phenotype The combination of observable characteristics expressed by a genotype which identifies a particular organism.

plasmid A small DNA molecule in a bacterium distinct from the chromosome.

poppy straw The dried, threshed capsules of the opium poppy. The raw material of opiate production.

Single Convention A United Nations regulatory regime that sanctions and coordinates opium production.

shattering Loss of crop through fruit or seed shedding by a plant. It is usually associated with crop maturity or external factors such as significant weather events or other changes in the plant environment. Disturbance of mature canola plants by harvesting operations can result in heavy losses through shattering.

thebaine An alkaloid used in the production of a new class of drugs including oxycodone used in the treatment of severe pain. It can also be converted into codeine. It occurs earlier than morphine in the biosynthetic pathway and so is present only at low levels in conventional poppy straw.

TOP 1 See Norman above.

transgenic Descriptive of an organism with a genotype containing genes transferred from another species with which it cannot breed. Often more loosely applied to all organisms containing artificially introduced genetic material.

triazines A herbicide group associated with persistence, movement and undesirable biological effects in the environment. They are widely used in conjunction with triazine resistant canola varieties (TT canolas).

vertical gene flow Normal reproductive movement of genetic material from an organism to its descendant.