The Tasmanian Poppy Industry: A Case Study of the Application of Science and Technology

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Abstract
Tasmania is the world's largest producer of opium alkaloids for the pharmaceutical market. The area sown to poppies is close to 20,000 ha, and the industry is one of the larger employers in the State.

The application of science and technology has been critical to the development of the poppy industry. High yielding varieties and efficient production methods allow the Tasmanian industry to compete successfully on the world market.

Farmers, government research agencies, and the processing companies have each been important in the development of new technology for the poppy industry. In recent years, the activity of government research agencies has declined and their role has largely been replaced by private enterprise.

The strengths of the industry include its strong market focus and the close relationship with poppy growers.

Key Words
poppy industry development alkaloid opium

Introduction
This paper discusses the role of science and technology in the poppy industry from the perspective of one scientist who has been involved in the industry since 1981. While this perspective may be considered somewhat narrow, the limited geographic spread and relatively short history of the industry assist an individual to provide a reasonably complete and balanced view. Because of its commercial nature, many of the statements made and work reported in this paper are not supported in published papers.

The Tasmanian Poppy Industry
The Tasmanian poppy industry is based on the opium poppy, *Papaver somniferum* L. This annual herb is one of the oldest cultivated plants known to mankind and the history of the human race is interwoven with the use and abuse of this plant (1).

Cultivation of poppy crops is restricted to Tasmania by ministerial agreement between the Commonwealth and the States. The industry is characterised by a high degree of vertical integration. The processing companies, Tasmanian Alkaloids and Glaxo Wellcome, are involved in agricultural research and provision of seed and advice to farmers, through to manufacture of active pharmaceutical ingredients (APIs). Each company contracts with about 700 farmers on an annual basis. At maturity, the dry crop is mechanically harvested, and transported to the processing plants. Growers are paid according to the alkaloid content of their crop, which provides a strong incentive for growers to maximise alkaloid yields. During processing, the crop is threshed to separate seed from poppy straw. The alkaloids are extracted from the poppy straw to produce concentrate of poppy straw (CPS), which can be sold as a narcotic raw material, or utilised in the manufacture of APIs. Concentrate of poppy straw generally contains between 40 and 80% alkaloid, with that produced in Australia at the upper end of the range. Tasmanian Alkaloids processes most of its morphine CPS into codeine and other APIs in Tasmania, whilst Glaxo Wellcome exports most of its production as CPS. Tasmanian Alkaloids also produces thebaine CPS which is predominantly used for oxycodone synthesis. The seeds contain no significant amount of alkaloids and are sold for culinary purposes.

Tasmania's Position in the World Opium Alkaloid Market Place
Australia produced 51% of the world's morphine CPS in 1998, the most recent year for which figures are available (2). Turkey produced 23%, France 21% and Spain 4%. The other major producer is India, which manufactures the traditional product opium. Opium contains approximately 10% morphine, and smaller

amounts of other alkaloids including thebaine. India's production of opium alkaloids is currently similar to that of Australia.

The UK and USA are the largest markets for CPS, importing 49 and 38 tonnes respectively in 1998. The USA is the largest importer of opium; 541 tonnes in 1998. The USA has a policy of sourcing 80% of its narcotic raw materials from the traditional producers, India and Turkey (the "80:20 rule"), and doesn't import APIs such as codeine phosphate.

Whilst thebaine is a minor constituent of opium poppies, it is the main alkaloid present in a new variety of *P. somniferum* developed by Tasmanian Alkaloids. Thebaine is not itself used in therapy, but is an important raw material in the manufacture of several opioids such as oxycodone and buprenorphine and nal-compounds such as naloxone and naltrexone. The major markets for thebaine are USA, where imports are not restricted under the 80:20 rule, and Europe. The majority of the Tasmanian Alkaloids crop is now sown to thebaine varieties.

Table 1 compares the efficiency of the Australian poppy industry with its major competitors (excluding India). Of the countries which grow poppies for CPS, Australia has 10.7% of the crop area, and produces 45.8% of the world's CPS. By contrast, Turkey has 46.5% of the area and produces 24.5% of the CPS. Australia's yield per hectare is 8 times that of Turkey, nearly twice that of Spain and 30% higher than France.
It is necessary for the Australian industry to have these yield advantages to compete in the world market. 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.

Table 1. Comparison of production figures averaged over 1994 to 1998 for countries growing poppy straw for use in production of CPS[1].

Country	Area		Straw harvested		Straw yield (kg/ha)	CPS produced[2]		Yield in CPS (%)[3]	Alkaloid Yield (kg/ha)
	ha	% of total	Tonnes	% of total		Tonnes	% of total		
Australia	8687	10.7	5904	19.4	686	81	45.8	1.28	9.3
France	5959	7.3	4806	15.8	805	42	23.6	1.08	7.0
Spain	1822	2.2	430	1.4	269	9	4.8	1.09	4.9
Turkey	37897	46.5	16231	53.4	426	43	24.5	0.33	1.1

[1]All data based on UN figures (2).
[2]The concentration of alkaloid in CPS varies. All CPS figures are corrected to 100% alkaloid basis.
[3]An estimate of straw alkaloid content (alkaloid in CPS/straw processed x 100). Note that this is after processing so actual content is higher.

Establishment of the Industry in Tasmania
The establishment of the poppy industry in Australia, and the public sector research is reviewed by Laughlin et al. (3). Early work was done in the late 1800s in NSW, and in the 1940s by CSIRO. The poppy industry was introduced to Tasmania in the late 1960s by the Edinburgh based company, Macfarlan Smith, a subsidiary of Glaxo. Macfarlan Smith had been doing trial work in the UK aimed at establishing the industry in that country, but finally recognised that the unreliable English summer was not suitable for poppy production. Their researcher, Mr Steven King, examined weather records for several countries and came to Australia with a view to establishing the industry in Victoria. The Victorian government was not interested in the proposal, and Mr King turned his attention to Tasmania, a location which he had previously overlooked due to not having climate data. He found the Tasmanian Department of Agriculture[1] a willing partner in establishing trials, and over several years Tasmania was confirmed as a suitable location for poppy cultivation. Glaxo established a crop reception facility at Latrobe, Tasmania, and converted a milk powder factory at Port Fairy on the south coast of Victoria, into an extraction plant for the production of CPS. Glaxo is now known as Glaxo Wellcome.

[1] The Tasmanian Department of Agriculture has had several name changes. Hereafter, the current name Department of Primary Industries Water and Environment (DPIWE) is used.

Tasmanian Alkaloids was established in 1975 as a joint operation between Abbott Laboratories and Ciech Polfa. Abbott Laboratories had a codeine manufacturing plant in Kurnell, NSW and were seeking to establish their own source of raw materials. Ciech Polfa was a Polish company with experience in the cultivation of poppies and extraction of poppy straw. The company was established at Westbury, where initially CPS and poppy seed were produced. The company was purchased by Johnson & Johnson in 1982, who moved the codeine plant to the Westbury site. Johnson & Johnson are manufacturers of the Tylenol range of pain medication, and purchase of Tasmanian Alkaloids was made to ensure a reliable source of raw materials.

Tasmania has proved to be an excellent location for the poppy industry. The crop fits well into a rotation with vegetable crops in the basaltic soils on the north west coast, and with cereal crops in the midlands and south. The cool temperate climate allows the plants to grow well during spring, and the relatively dry summers allow harvest of crops with little need for artificial drying. The cool climate allows production with only sporadic problems from *Helicoverpa* and other insect pests which would be a significant problem in warmer areas. These natural advantages combined with technological developments and skilled farmers have enabled Tasmania to consistently produce the highest alkaloid yields in the world (Table 1).

The isolation of Tasmania is also an advantage for narcotic security. Tasmania has an excellent record in security and is the benchmark for other producing nations.

Growth of Industry

When the industry was in its infancy, poppies were not a popular crop amongst many growers. The crop failure rate was high and the factors affecting alkaloid content were not well understood, so growers were often disappointed by achieving low returns on what appeared to be good crops. Weed control was often poor, resulting in a build up of weeds.

With the development of high yielding cultivars, an understanding of nutritional and irrigation requirements, and development of reliable weed control methods, the popularity of the crop increased with growers, and gradually the area increased from less than 4000 ha in 1987 to almost 20,000 ha currently (Figure 1). The area sown to poppies is currently equal to that sown to potatoes, peas, green beans, onions, brassicas and pyrethrum combined. The success of the industry is due to the capacity of Tasmania to compete on the market with overseas producers, whilst paying growers, contractors and employees a fair return for their efforts. Efficiencies brought about by the application of science and technology have been a critical contributor to this success.

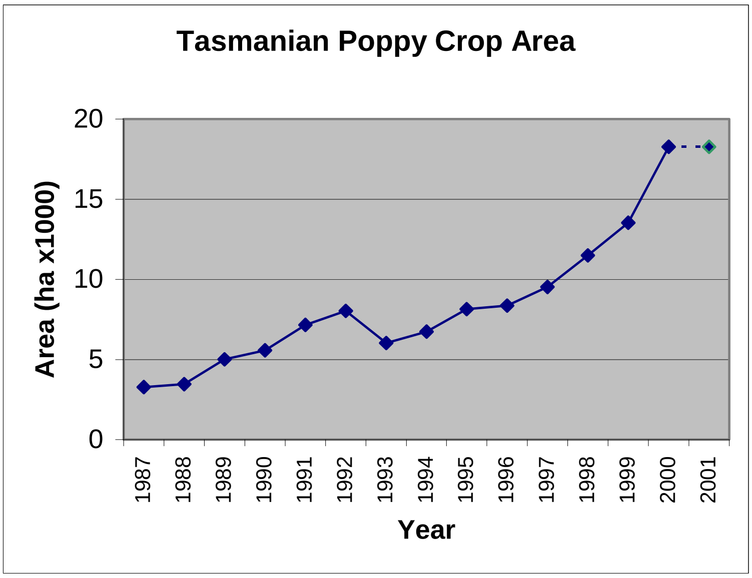


Figure 1. Area of poppies grown in Tasmania (2).The figure for 2001 is an estimate.

Role Of Science And Technology In The Tasmanian Poppy Industry

The basic requirements of the industry are crops with a high alkaloid percentage in the straw, and a high alkaloid yield per hectare. High alkaloid crops allow efficient extraction of alkaloids. Processing costs are either fixed (depreciation, wages, maintenance), or depend on the volume of the straw processed (e.g. crop transport, crop storage, extraction). Thus, the cost of producing a kilogram of alkaloid is substantially less with higher alkaloid content crops.

Alkaloid yield has little relevance to the extraction process, but is important for two reasons. The industry is confined to Tasmania which has a limited amount of land suitable for poppy cultivation. Therefore, increases in production increasingly depend on the achievement of additional yield, rather than increasing area of cultivation. Additionally, the return per hectare must be sufficient for poppies to compete against other agricultural enterprises. Commercial alkaloid yields are now approximately 3 times those achieved when Tasmanian Alkaloids first started contracting poppy crops.

Alkaloid yield is a product of straw yield and the straw alkaloid content (Figure 2). The major factors affecting alkaloid % are the genotype and the nitrogen nutrition of the crop. Straw yield is influenced by genotype, nitrogen and phosphorus nutrition, soil water status (rainfall) and weeds, pest and disease. Innovations which influence alkaloid content in the straw are more valuable to the industry than those which influence just straw yield. This is because increases in alkaloid content create improvements in alkaloid yield as well, fulfilling both requirements.

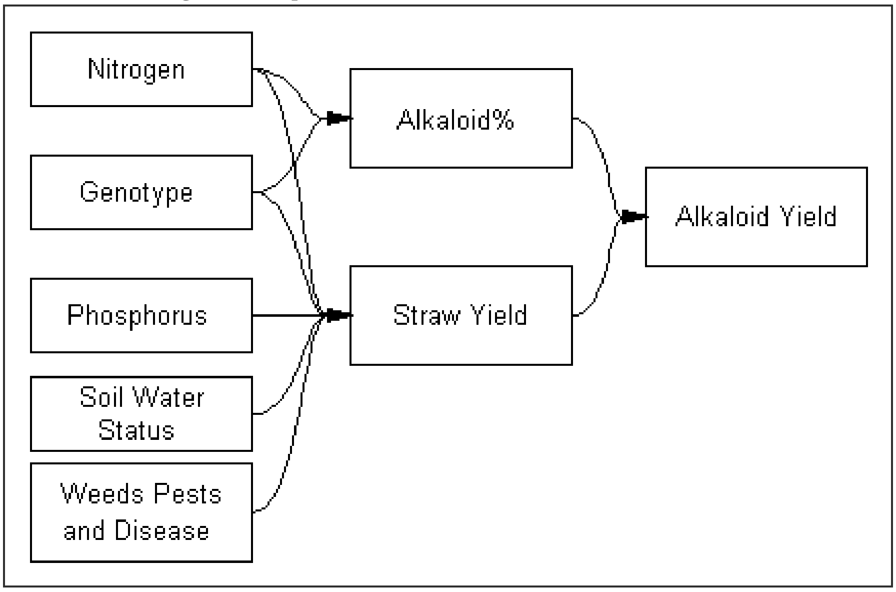


Figure 2. The relationship between straw yield, alkaloid % and alkaloid yield, and the factors which have the main influence on these outcomes.

Examples of Science and Technology in the Poppy Industry

Understanding the climate required for poppy cultivation, and utilisation of weather data in the selection of Tasmania by Stephen King was probably the first and most basic use of science and technology in the development of the industry. There have since been many developments in the industry which have contributed to the very strong position which it now holds in the local economy. These are summarised in Table 2. Due to the nature of the industry, few of these developments have been described in the scientific literature. Three developments are described below to illustrate a range of projects familiar to the author.

Example 1. Cost Reduction in Weed Control through better Understanding of the Mechanisms Involved.

Diquat (Reglone ®) was the first herbicide used in poppies (4). Diquat is usually considered a non-selective herbicide with best effects on broadleaf weeds. However it causes little damage to poppies, due to the surface characteristics of poppy leaves. It was found that mixing diquat with various herbicides increased the range of broadleaf weeds controlled (4). A number of different herbicides have been used to mix with diquat. The most recent was Hoegrass ® (diclofop-methyl). This was surprising, as diclofop-methyl is normally active only against annual grasses. In fact, in small plot trials conducted by Tasmanian Alkaloids, it was found that mixing an emulsifiable concentrate (EC) insecticide with diquat had the same effect. Therefore the hypothesis was formed that the EC formulation of the added product, rather than the active ingredients, modified the activity of diquat. This idea lead to a research project conducted by Tasmanian Alkaloids and a collaboration with the School of Agricultural Science, University of Tasmania. The research at Tasmanian Alkaloids involved testing a wide range of surface-active agents to evaluate their effect on the efficacy of diquat.

The work at the University investigated the effect of adjuvants on the contact angle between a diquat-containing water droplet and the leaves of poppies and weeds (5). It was shown that the adjuvants modified this contact angle, increasing the wetting effect of the droplet. Poppies were found to be harder to wet (higher contact angles) than the major weeds. A Hoegrass EC Blank formulation (diclofop-methyl absent) had the same effect as Hoegrass, proving the hypothesis that the herbicidal additives to diquat were effective by virtue of their excipients. This allowed the identification and marketing of an adjuvant as a replacement for EC herbicides, with a saving to growers of $37 per hectare.

In this example, the initial idea came from Tasmanian Alkaloids. Serve-Ag (a Tasmanian agribusiness company) supplied samples of a wide range of wetting agents, and the University of Tasmania provided the data that proved the hypothesis. The close relationship between Serve-Ag and Tasmanian Alkaloids also assisted in the new product being brought to market. This was one of many small improvements to the weed control strategies originally devised by the DPIWE (4).

Example 2. Development of Nitrogen Nutrition Guidelines

Work conducted by DPIWE (summarised by Laughlin et al., (3)), showed that in some circumstances poppies would respond to top-dressed nitrogen. However, it was recognised in the industry that not all crops would respond, and the use of top-dressed nitrogen was very small due to this uncertainty. Tasmanian Alkaloids started work on nitrogen nutrition of poppies in 1988 following discussions with DPIWE. At the same time Serve-Ag introduced a rapid sap testing service for leaf nitrate. The project determined critical nitrogen concentrations in leaf tissues for alkaloid percentage in poppy straw (Figure 3), and demonstrated that significant increases in crop alkaloid content could be achieved by optimising nitrogen nutrition at the hook stage (Figure 4). In this example, the final alkaloid content in the straw was increased from 1.38% to 1.68% following a single nitrogen application at early hook stage. Field testing showed that in some years virtually all crops required nitrogen top-dressing, whilst in other seasons, only some crops were deficient. Company field officers now promote sap testing and nitrogen applications. Adoption rates of the strategy have increased to quite high levels, and the occurrence of unexpectedly low alkaloid content crops is very much lower than it was 10 years ago, largely due to the recognition of nitrogen deficiency as a major cause of low alkaloid content.

Figure 3. Relationship between Sap Nitrate and Alkaloid%

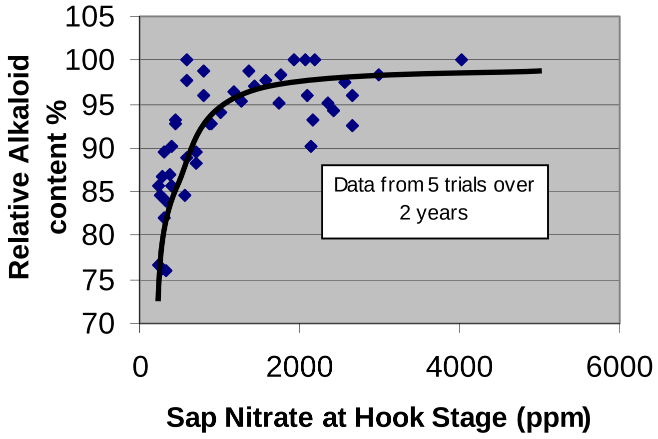
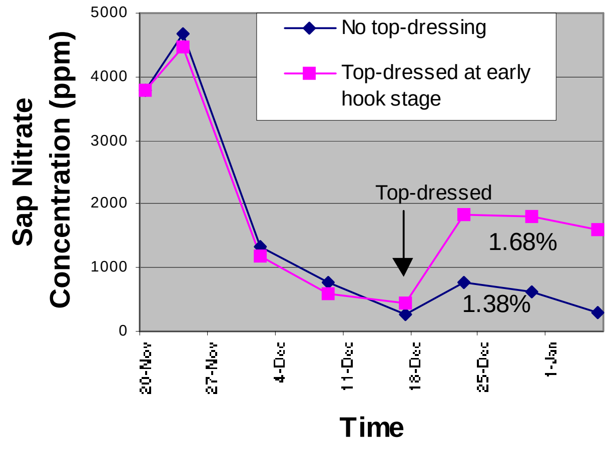


Figure 4. Example of Response to Top Dressed Nitrogen

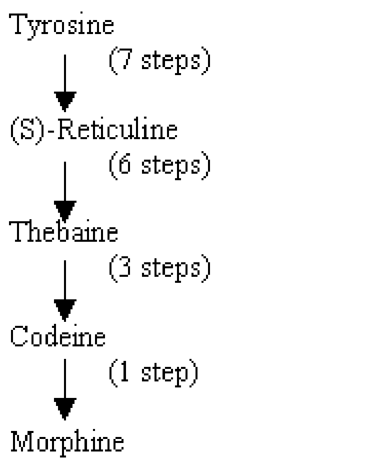


In this example, the DPIWE provided the initial research results that demonstrated the potential benefits from top-dressed nitrogen. DPIWE also had expertise in sap nitrate testing, which was utilised by Serve-Ag in providing the commercial sap testing service. Tasmanian Alkaloids recognised the need to identify the critical plant nitrate concentrations, conducted the research, and promoted the strategies to growers.

Example 3. Development of Thebaine Poppy

Until 1996, Tasmania was a small producer of thebaine, which was extracted from poppies grown primarily for morphine. For several years, Tasmanian Alkaloids cultivated varieties with enhanced thebaine content, up to about 15% of the morphine content depending on the dryness of the growing season. However, thebaine was difficult to extract from these varieties because it separated into "tarry" fractions during processing. Researchers at Tasmanian Alkaloids recognised that there was a possibility of breeding a poppy variety in which the biosynthetic pathway stopped at thebaine instead of going on to produce morphine (Figure 5). Nyman and Hall (6) had previously selected a spontaneous mutant containing high thebaine content, but after many years attempting to breed a pure line of this variety, concluded that the mutant had a chromosomal instability and a large proportion of each new generation regressed to a morphine type (7).

Figure 5. Biosynthesis of Morphine in *Papaver somniferum*.



A research project was established at Tasmanian Alkaloids in 1994 in order to develop a high thebaine poppy variety to meet the anticipated demand. Several methods to block the synthetic pathway at thebaine were considered. The merits of mutagenesis versus genetic engineering were debated and the decision was made to utilise mutagenesis, which has proved wise considering the uncertainty regarding genetic engineering. Prior to starting a mutagenesis program, the techniques of inducing the appropriate rate of mutation, and most importantly, the screening techniques, were developed. Mutagenesis has been used in *P. somniferum* previously but the alkaloid content of large numbers of individual plants had never been tested. Tasmanian Alkaloids developed an analytical method capable of screening 1000 plants per week. The method utilised a tiny droplet of latex collected from an excised leaf. The droplet was extracted in a buffer, and analysed by HPLC utilising a very rapid method. This allowed non-destructive qualitative analysis of young seedlings for the major alkaloids found in latex. Plants with unusual alkaloid profiles were re-tested, and those passing the second test were grown to maturity.

A large number of alkaloid mutants were selected from the M_2 population using this method. The most important selection commercially was the 233rd selection, which came to be known as Norman. This plant was free of morphine and codeine, and its latex contained just two major alkaloids, thebaine and oripavine. Oripavine has never previously been available in quantity. It can be methylated to produce thebaine, using a similar process to that used to produce codeine from morphine. Subsequent generations have shown that the morphine-free characteristic is due to a single recessive gene. This new variety was first grown commercially in 1996/7 (500 ha). Since that time the crop area sown to this variety has increased at 50-100% per annum, and it now comprises more than 60% of the crop contracted to Tasmanian Alkaloids. Norman produces approximately the same quantity of alkaloid per hectare as conventional varieties, but as thebaine and oripavine instead of morphine.

The development of the Norman poppy coincided with the release of a slow release formulation of oxycodone in the USA. Oxycodone is used in treatment of strong pain, mostly in terminally ill patients. The new formulation was very successful, and there was greatly increased demand for the thebaine raw material used for its manufacture. The high demand has caused an increase in crop area in India, as well as allowing growth of thebaine crop area in Tasmania. The Indian production however has caused an overproduction of morphine, which is likely to depress prices for both morphine and codeine.

This new poppy variety is a major turning point in alkaloid production. For the first time, thebaine can be produced efficiently without concomitant production of morphine. High alkaloid *P. somniferum* poppies can be grown without risk of diversion for illicit purposes: thebaine and oripavine are not easily converted into morphine or heroin. Thebaine can be converted into codeine, which is currently the largest volume API produced from opium alkaloids, so perhaps virtually all the world's opium alkaloids will eventually come from poppies having the Norman mutation.

This innovation, like most of the plant breeding projects in the poppy industry, had virtually no input from the public sector. The ideas developed from discussions in Tasmanian Alkaloids and Johnson & Johnson Research, a J&J Company based in Sydney. It drew on the expertise of analytical chemists, geneticists and agriculturists within the companies.

Discussion

In the early stages of the industry, DPIWE took a leadership role in much of the agronomic research for poppies. Poppy nutrition, irrigation requirements, responses to lime, optimum densities, and crop protection methods were determined by work conducted at government research stations. This research laid an important foundation for the industry. Plant breeding research has been the province of the processing companies since the industry's inception.

Farmers have been involved in a number of important innovations. In the beginning it was a matter of necessity: the crops had to be harvested! Farmers are still involved in innovation, but perhaps in a more incremental way. Recently, individual farmers have been recognised for developing improved crop-lifters for harvesters, enabling harvest of lodged crops (8), and for inventing a rapid method of adjusting wheel spacing for drills used in raised-bed paddocks (9). Two recent innovations have been adopted from other crops or areas. Raised bed farming was adopted from Victoria by farmers working together in the Southern Farming Systems organisation. Use of raised beds has been critical in increasing Tasmania's poppy crop area to the current levels. Centre pivot and lateral move irrigation systems were adopted very slowly initially. DPIWE conducted research in the late 1980s showing that water could be applied more evenly through these systems than through the more common gun irrigators. Assistance given by the potato processing company, Simplot, to farmers to purchase centre pivots appears to have been the critical step that precipitated widespread adoption. Farmers now are often purchasing these systems primarily for use on poppy crops.

Developments in crop protection and nutrition over the last 15 years have been lead by the poppy companies on a background of information developed in the public sector in the earlier years. The poppy companies now lead and initiate virtually all the poppy research undertaken in Tasmania, and the public sector is a very minor part of the picture. The major focus of the companies is on plant improvement. Development of higher yielding varieties have been critical in the survival of the industry against countries where the poppy industry is used as a rural support scheme.

The research model used in the poppy industry is quite different to others in Tasmania and Australia. The research is fairly applied and very market focussed. Virtually all of the poppy research conducted in Australia is done by company personnel or directly funded by the companies. Research corporations such as HRDC support a small number of projects in relatively non-competitive areas such as disease research. Farmers do not pay levies, and have a minor role in the direction of research. However, due to the close relationships between the companies and the growers, the growers' needs are well understood and taken into account.

The market focus is one of the major strengths of the poppy industry. Researchers work together with colleagues involved in marketing and in field operations. This has the effect of keeping the research very relevant to the company's products and customers. Another strength is the strong extension effort. Approximately 30 company field officers work on a one to one basis with poppy growers, and advise on all aspects of poppy crop production. Growers are very receptive of new technology, and uptake is rapid. A particular strength at Tasmanian Alkaloids is the integrated company structure. At the one site, poppy varieties are developed, poppy straw is processed and active pharmaceutical ingredients are manufactured and marketed. This provides a tremendous depth of knowledge and experience, and a very motivational environment in which to conduct research.

A possible weakness of the current system is that due to the strong lead taken by the processing companies, the public sector has tended to consider the poppy industry as self-sufficient, and public research dollars have favored other crops. Opportunities have probably been lost as a result.

Conclusion

The Tasmanian poppy industry needs a competitive advantage in order to compete against foreign competitors who receive extensive government assistance through protected monopolies and subsidies. The high alkaloid content of the Tasmanian crop is our most important competitive advantage. Science and technology have been critical in providing this edge.

The industry has a strong commitment to research, and growers are very supportive of the research effort and readily accept new technology. Whilst most of the current research and development is lead by the processing companies, poppy growers, government research agencies, and agribusiness have all been partners in this success.

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Table 2. Scientific and technological developments important in the development of the Tasmanian poppy industry. For each issue, the background is summarised, the critical development is identified, and the organisation having the major influence on the development is indicated. The new practices are described and the beneficial outcomes are listed. The dates given are approximate.

Date	**Issue**	**Background**	**Critical research/development**	**Major Influence**	**Practice**	**Outcome**
1975	Harvesting	Grain headers found to be unsuitable due to humidity in coastal Tasmania.	Grain headers modified by farmers. Farmers also involved in critical steps in introduction of forage harvester technology.	Farmers	All modern poppy harvesters use principles developed.	Harvesting can occur in humid conditions.
1975	Morphine yields	Alkaloid yields recognised as important	Company breeding programs	Companies	New varieties regularly introduced.	Global competitiveness maintained.
1976	Boron deficiency	Known in Europe. Deficiency symptoms found in crops when area extended into alluvial soils.	Symptoms confirmed as boron deficiency. Responses shown to boron top dressing.	DPIWE	Boron applied to susceptible soil types at sowing. Where boron deficiency develops it is usually recognised and treated quickly.	Crops grown successfully on B deficient soils.
1983	*Pleospora* Control	Crop losses due to *Pleospora*.	Research shows importance of crop rotations, stubble management and seed dressings.	DPIWE	Seed dressings, 3 yr crop rotations Stubble destroyed by burning or slashing and burying.	*Pleospora* not a significant problem.
1987	Irrigation	Poppies introduced as dryland crop.	Critical times for irrigation, and demonstrated the large response to irrigation.	DPIWE	Irrigation guidelines are widely followed.	Increased yields. Increased percent of farmers use irrigation.
1990	Weed control	Inter-row cultivation found not to be satisfactory in krasnozem soils. Poppies are too small a crop for specific development of herbicides	Selective weed control programs developed. The major breakthroughs were identification of diquat as a selective herbicide for poppies (4) and the introduction of asulam / ethofumesate tank mixes (Glaxo research).	DPIWE (especially early on) Companies Serve-Ag Research	Selective herbicides used universally.	Most crops weed free. Few crops fail due to weed infestations.

Date	**Issue**	**Background**	**Critical research/development**	**Major Influence**	**Practice**	**Outcome**
		by chemical companies.	A number of smaller advances have been made in the last 15 years, such as the introduction of Alta Adjuvant and Command (clomazone).			
1992	Nitrogen nutrition	Work by DPIWE showed favourable responses in many circumstances.	Establishment of critical sap nitrate concentrations.	DPIWE + Tasmanian Alkaloids	Company field officers test sap nitrate and recommend N top-dressing accordingly.	Higher and more consistent alkaloid %.
1996	Thebaine yields	Thebaine produced as a byproduct of morphine extraction. Increasing requirement for thebaine.	High thebaine varieties developed with no morphine	Tasmanian Alkaloids	Thebaine specific crops grown and extracted	Supply of high quality thebaine to market without concomitant production of morphine.
1997	Downy Mildew	Downy mildew became a widespread and serious threat to poppy crops	Identification of the disease, development of protective and eradicant strategies (using downy mildew strategies in other crops as a model).	Companies, Serve-Ag Research	Widespread use of spray programs.	Reduced losses to this disease.
1998	Raised beds	Need to increase poppy area. Controlled traffic research done by DPIWE.	Adoption of technology from Victoria	Southern Farming Systems[1]	Approx. 2500 ha of poppies grown on raised beds in 2000/2001 season.	Increase in amount of land available for poppy crops. Increased yields due to earlier plantings and improved drainage.
1998	Centre Pivot irrigation	Gun irrigators recognised as being uneven. Growers looking to efficiently irrigate larger areas	Potato companies encouraged use of centre pivot irrigation. The technology was then used on other crops in the rotation.	Potato companies	Centre pivot and lateral move irrigation in widespread use, often in conjunction with raised beds	Higher yields. Lower labour requirements.

[1]Southern Farming Systems is a farmer controlled RD&E organisation.