Genetically Modified Cottons – Costs and Expectations

Dave Anthony, Auscott Limited, Australia

Introduction

Insect invasions of agricultural crops pose an incredible challenge to modern societies. Awakened to action by the weather, nurtured by favorable vegetative refuges and faced with running the gauntlet of marauding predators, the vast armies of agricultural pests persistently challenge human aspirations for food and fiber production. Gene technology offers exciting benefits to farmers, consumers and the environment in managing these production challenges.

Australian cotton growers are very aware of the benefits of gene technology following four years of commercial experience using genetically modified cottons to manage *Helicoverpa* species (*Heliothis*). These cottons, marketed as Ingard varieties, contain a gene (Cry 1Ac) from the common soil bacteria Bacillus thuringiensis (Bt) conferring resistance to against *Helicoverpa* species of bollworm and budworm. As a result reductions of up to 52% in pesticide use have been obtained over the past four years.

However, a growing challenge to this technology is coming not from the traditional combatant, the insect, but from the very people who will be the technology's beneficiaries—the consumers and environmentalists. It is also fair to question whether trade-related issues are also playing a part in the current GMO (genetically modified organism) debate.

Initially humans hunted and gathered their food and fiber needs. Systems of agriculture developed over time, with crop and animal husbandry providing the bulk of daily work for most people. Today however, we go shopping for food with our lives fully occupied with the routines, commerce and trappings of modern living. Contemporary society's understanding of the challenges of agricultural systems has become superficial focusing on "droughts and flooding rains" rather than the complex challenges of production systems. Today's consumer, far removed from the production face, expects agriculture to deliver ample supplies of high quality, reasonably priced safe food and fiber.

So with these expectations and the benefits being noticed down on the farm, why have genetically modified organisms (GMO's) faced so much controversy? Forgive the plagiarism but "a funny thing happened on the way to the market." Developers and proponents of these promising gene technologies didn't do enough work with the consumer!

Appreciating the benefits of biotechnology and understanding the challenges for food and fiber production are crucial to the future success and adoption of biotechnology in agriculture. In Australian cotton the benefits now and in the future will be immense, not only to farmers but also to the broader community. Relaying this message simply and factually in the emotion charged global GMO debate is a considerable challenge.

Gene Technology – Its Role in Crop Improvement

Gene technology is a tool in plant breeding and not an end in itself. Traditional plant breeding remains the central mechanism of crop improvement looking to biotechnology to supply desired traits in a timely and more efficient manner.

Mankind has been trying to improve plants since the creation of agriculture. Selection of better plants from which to increase yields occurred back in antiquity. Plant breeders have incorporated useful genes into valued plants through cross breeding since Mendel unfurled our understanding of traits and genes. Modern wheats with their resistance to rust fungi obtained their disease fighting genes from goat grass. The chance of this transfer of useful genes happening naturally and in an acceptable timeframe for modern man was remote. Mutagenesis has been used for decades to generate new genes or gene combinations. These have been incorporated into a wide range of horticultural and agricultural plants. The development of hybrids, which significantly impacts on gene combinations, has been one of the important milestones in human food production. Today we see the incorporation of insect-resistance genes into cotton through a new plant improvement system called biotechnology.

Plants have long fought diseases and insects through natural genetic developments. They have developed their own pesticides (some of which are carcinogens) to ward off predators. They have adapted to a wide range of soil, moisture and climatic conditions through genetic changes. We would be arrogant to believe these developments of nature were designed to suit mankind. On the contrary, humans have selected, modified and manipulated plants to meet food and fiber needs for thousands of years.

Gene technology should be seen as another step in mankind's striving for better and more useful gene combinations. With our increased understanding of plant genetics, combined with greater analytical and testing procedures, we can identify and transfer specific useful genes more safely and efficiently. Like the advancements in computers, communication and travel, so genetic improvement must use the best tools available.

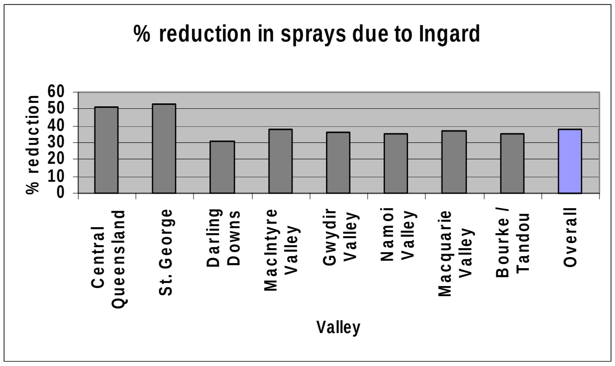
Biotechnology in Australian Cotton – Insect Control

Cotton, while not a favored host of *Helicoverpa*, finds itself embroiled in control strategies with this pest each season. Grains and pulse crops, especially chickpeas, sorghum and edible beans, can be ravaged by these caterpillars. Numerous chickpea crops on Queensland's Darling Downs failed in the 1997/98 season under the wave of *Helicoverpa* pressure. In Australia, the 1998/99 cotton season was one of those seasons where the pest complex including tipworm (*Crocidosema plebejana*), aphids and mites as well as the old foe, *Helicoverpa*, gained significant ascendancy over growers.

A continuously wet winter in 1998, including significant flooding, decimated many eastern Australian wheat crops and encouraged rank weed growth across much of the cotton belt. For whatever reason, the disease problems in wheat coincided with a general paucity of thrips, a useful and aggressive predator of mites in cotton which normally help minimize the early season use of broad spectrum cotton sprays. Other natural predators including hover flies were also at very low levels. The luxuriant weed growth throughout cotton growing areas provided an ideal refuge for tipworms who invaded the young cotton crops in numbers not seen since the early 1980's.

Supporters of integrated pest management (IPM) in cotton who rely on the annual influx of early season predators found themselves exposed on the non-Ingard cotton. Aphids appeared unusually early, along with *Helicoverpa punctigera* and *H. armigera* in their typical waves. These insect problems, combined with a low heat unit summer, resulted in very ordinary and at times unprofitable yields for many growers. Those who resorted to pesticides early achieved, on average, higher yields but at a considerable economic cost.

Despite 1998/99 being one of the worst insect years, transgenic Bt cottons (which accounted for 20% of cotton plantings) required on average 38% less insecticide

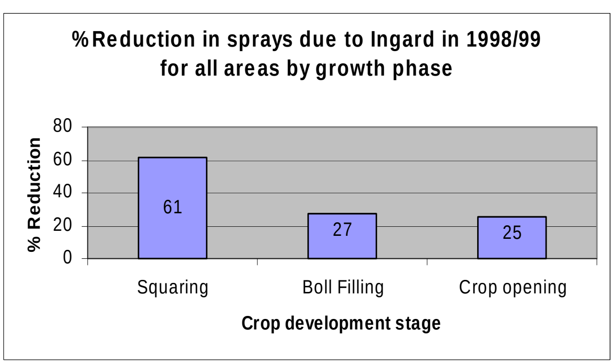


Graph 1. 1998/99 Cotton season – reductions in insecticide applications by production area in Australia through the use of Ingard cotton.

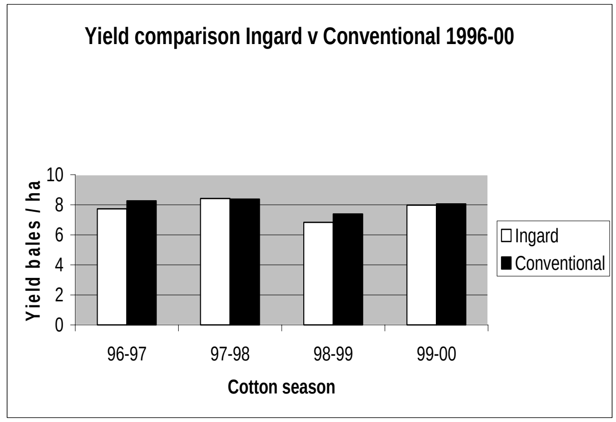
than conventional cotton (CRDC 1999). Graph 1 shows the percentage reductions in pesticide use on Ingard fields compared to conventional cotton during 1998/99 across the main cotton growing areas of Australia. Endosulfan usage was reduced by 71% on Ingard fields. Over the three seasons in which Ingard has been commercially available in Australia, Bt cotton has provided its greatest benefits during the first half or squaring to early flowering phases of each cotton season (Graph 2).

Of particular interest in the 1998/99 season was the effectiveness of Ingard against tipworm. This was a particularly bad early season pest in that year, however the Ingard fields required 85% less spraying to control this pest.

The yield differences between conventional and Ingard cotton vary from season to season. Graph 3 (CRDC 1997, 1998, 1999 and 2000) shows the yield differences between conventional and Ingard cotton over four seasons. Overall in 1996/97 Ingard yielded 6% less than conventional cotton; 0.5% above in 1997/98; 8% lower in 1998/99 and 1% lower in 1999/00. The yield difference varies from region to region. For example, in 1998/99 in central Queensland, Ingard yielded 7% higher than conventional cotton and was also ahead in the Bourke and Macquarie



Graph 2. Reduction in pesticide use over the various crop stages for Ingard versus conventional cotton across the whole industry in 1998/99.



Graph 3. Yield comparison over four seasons between Ingard and conventional cotton for the Australian cotton industry.

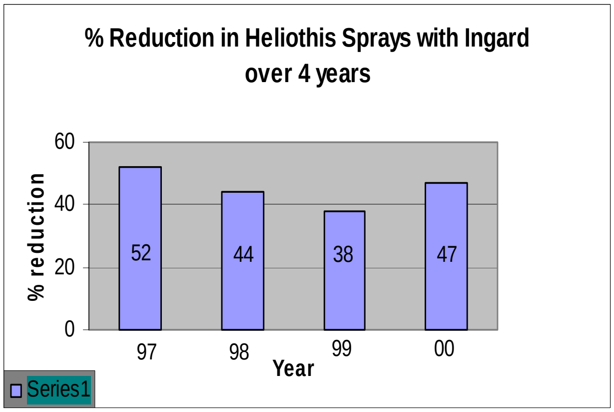
Valleys. It was significantly lower in the Gwydir Valley, but this is believed to be due to management issues not related to Ingard per se. Variability between years is related to the level of Bt expression in plants, which is largely influenced by environmental factors. Ingard performs relatively better in warmer, higher radiation years. This is supported by the more consist results in the Kimberley region where heat and sunlight are at higher and more uniform levels.

Despite the variability in relative performance, the economics of insect resistant cottons like Ingard is encouraging. If the price of this technology could be brought down to the same price paid by American cotton growers, then the economics of Ingard would be substantially improved. While benefits seem to have accrued, many Australian cotton growers would argue that the pricing of the current Bt technology has prevented greater reductions in production costs being realized. Table 1 shows the economic benefit (or deficit) of Ingard over conventional cotton for three seasons 1997/98, 1998/99 and 1999/00. The 1996/97 year has been left out of this table. In that year the economic performance of Ingard was much poorer than con-

Table 1. Economic Benefit (cost) of Ingard in Australia $ per Hectare - 1997/98 to 1999/00

Region	1997/98 $ / ha	1998/99 $ / ha	1999/00 $ / ha
Central Queensland	164	422	35
St George	193	82	56
Darling Downs	84	-39	119
Macintyre	-73	68	29
Gwydir	-111	-325	123
Namoi	39	14	71
Macquarie	147	46	26
Bourke / Tandou	64	185	72
Overall	$22	$6	$72

Table adapted from Pieter Kwint Consulting Pty Ltd and obtained from CRDC



Graph 4: Reduction in Heliothis sprays through use of Ingard over 1996/97 to 1999/00 seasons.

ventional cotton due to the higher license fees for Ingard. The net fee was reduced in subsequent years. It was also the industry's first commercial experience with the technology with initial expectations of performance exceeding the field performance in a cooler, more overcast year.

The overall economic benefit of Ingard has varied from $6 to $72 gain per hectare. Within regions however, as indicated above, there is considerable variation with some areas experiencing deficits while others receiving greater benefits.

The importance of Ingard in reducing Heliothis sprays cannot be underestimated. Graph 4 shows the results of four commercial years of Ingard experience. It should be remembered that 1996/97 was the year of Ingard's introduction while 1998/99 was one of the toughest insect years the industry has experienced.

The benefits from Bt cotton technology for Heliothis management are clear from the results in Graph 4. As we move through the "dawn" of this new technology, these results are very encouraging.

The 1998/99 season was also the first wider scale testing year of the two-Bt gene cotton technology known as P1 (Cry 1Ac) + P2 (Cry 2A). Plots up to four (4) hectares were involved in these trials (regulatory and agronomic). The two-Bt gene technology gave outstanding insect control, showing significant efficiency over commercial Ingard. It also provided control throughout the season, not just in the early stages. Its yield performance was very similar to single-gene Ingard under fully sprayed test conditions and was within just a few percent of the conventional varieties. Thus the concerns over any significant yield penalty do not seem warranted, given the superior insect control provided.

In other trials similar yields were obtained between two-Bt gene cotton, Ingard and conventional cotton, but with only the use of one and four sprays respectively for the former compared to seven for the latter.

Table 2. Relative Yield of Two-Bt Gene Cotton on Auscott Narrabri when Completely Unsprayed (Henggeler 1999)

Line	Relative yield
Conventional Siokra V 15	34%
Ingard Siokra V15i	84%
Two-Bt gene Siokra V15ii	100%

On Auscott Narrabri, a completely unsprayed large scale trial involving conventional, Ingard and two-Bt gene cotton using a common Siokra V15 background showed the following relative yields (Table 2).

The outstanding performance of P1 + P2 cotton shows the capabilities of this bio-technology to significantly reduce pesticide use. The biotechnology company Monsanto claims to have a superior gene known as Cry X which would be used in place of the P2 gene. The industry keenly awaits the outcome of testing this combination.

Apart from reductions in pesticide use, Bt cotton provides several other benefits including greater use of IPM and better environmental performance.

Bt cotton provides a non-disruptive platform on which to build an IPM system. By not having to use a conventional insecticide early in the season, natural predators are allowed to build up complementing Ingard's activity. Predator food sprays such as Environfeast can be used more effectively in Ingard crops as a consequence of reduced pesticide use.

In the 1999/00 Australian cotton season, Bt cottons represented approximately 30% of plantings. With the endosulfan residue problems in cattle, combined with concerns over riverine pesticide levels, Bt cotton has an important role near sensitive areas or property boundaries. Planting Bt cotton adjacent to stock routes or neighboring pastures significantly reduces the chances of endosulfan movement onto these areas.

Currently Ingard has a monopoly position in the Australian cotton industry. As a consequence, there has been minimal competitive price pressure. In time new products will enter resulting in either better value or lower prices for Bt licenses. Already, through united and concerted industry efforts, Ingard prices have been driven down from an initial $245 per hectare to $155. It is important that Ingard, or any other genetically modified cotton, adds true and substantial value to cotton production. There is a perception that cotton is a crop that can stand substantial increases for the prices charged for its inputs. This perception is not reality. Margins on Australian cotton are being squeezed and insect management is the highest cost area. Growers want to see the cost of insect management per unit of production fall. This would be a true efficiency gain and is an important key to providing benefits to consumers and the community.

Reduced costs of biotechnology can be achieved by combining the research capacity of institutions like CSIRO and Australian universities with commercial partners and rural industries. By engaging Australian researchers to improve the performance of useful genes to suit Australian conditions, greater benefits will flow to all parts of the Australian economy as well as to overseas owners of these genes. Australian cotton farmers have shown a huge willingness to invest in biotechnology but want to do so in a partnership that recognizes the future prosperity of all partners. Increased competition between biotechnology providers will certainly encourage such partnerships.

Biotechnologies in Australian Cotton – Soil & Weed Management

Cottons resistant to the herbicide glyphosate have been tested in the Australian cotton industry but are not commercially available. Herbicide-tolerant cotton offers considerable scope for developing improved minimum tillage and retained stubble-farming systems and reducing the dependence on residual soil-incorporated herbicides.

Unfortunately, concerns over supposed increases in herbicide use have dampened the introduction of this technology. Most cotton farmers believe the opposite will happen and point to a lack of practical understanding of farming systems by the critics and detractors of herbicide resistant crops. Interestingly, much of Australia’s huge canola crop is planted to a triazine-tolerant variety. The herbicide tolerance was introduced using traditional plant breeding techniques, which highlights the contradictions and complexities of the GMO debate.

Other Opportunities for Biotechnology in Australian Cotton

We are in the sunrise phase of biotechnology. Knowledge of plant genetics and ways to improve the quality and productivity of agricultural systems is growing rapidly. For a society that questions the use of pesticides and artificial fertilizers, gene technology offers a vehicle by which dependence on such inputs can be minimized while maintaining or improving agricultural productivity.

Biotechnology innovations in cotton offer exciting opportunities in disease management, water use efficiency and fiber improvement. By enhancing the cotton plant’s natural resistance mechanisms to disease attack or by creating a cotton plant that fixes nitrogen, the benefits to society will be immense. Ultimately production systems that are more efficient and productive will flow through to more competitively priced and abundant produce. There is no question that continued improvements to existing agricultural systems would reduce the need to clear more land for agriculture.

It is important that consumer concerns over gene technology are addressed so that this technology can move forward with confidence. Biotechnology changes everything in agriculture and science just as the Internet has changed everything in communications and commerce.

Biotechnology in Human Health

It is important to mention that while the debate on GMOs in agriculture is intensifying, a revolution in human medicine using gene technology has been proceeding with very little controversy. Currently some 80 biotechnology drugs are on, or are about to come onto, the market (Ernst & Young 1999). Many of these products involve recombinant DNA material, which is either swallowed or injected directly by humans. Well known products such as insulin are the result of biomanufacturing and are known as biopharmeceuticals.

We shouldn’t forget either that much of the rennet used today in cheese production is produced from non-animal sources using gene technology in microorganisms.

Clearly the linkage with human health benefits has overcome the ethical and emotional hurdles of this biotechnology. In the future cancer treatments, genetically caused deficiencies, allergies and other human diseases will be treated with biopharmeceuticals as knowledge and experience develop.

Agriculturalists have to convince society that benefits in food and fiber production through gene technology are no different in principle and purpose to gene manipulation for human health.

Are There Alternatives to GMOs in Agriculture?

In today’s hectic world, consumer expectations of reliable supplies of good quality, affordable food and fiber products reflect society’s chief consideration of agriculture. In many western economies up to 70% of populations have never stepped foot on a commercial farm. Popular media increasingly shapes the consumer’s fleeting knowledge of agriculture. Folklore and sentimentalism also play a role in denying consumers a real understanding of food and fiber production in the new millennium.

Modern agriculture clearly has to operate on business principles. Its wages, working conditions and adoption of technology must compete with other sectors of the community. Agriculture however carries important responsibilities not borne by many other sectors. These include natural resource management and the supply of life essentials such as food and fiber. The need to maintain or enhance productivity to meet increasing world population growth is critically important. This latter point is essential in avoiding agriculture’s competition with urbanization. Furthermore, preservation of wilderness areas and natural vegetation resources will only come if existing agriculture can improve productivity on its existing lands.

The productivity achievements of agriculture stand as one of the foundation stones of society. Through advances in agricultural productivity western populations have been able to move most of their human resources from food production to secondary and tertiary industries.

Native and traditional plant species simply cannot turn sunlight, nutrients and water into human nutritional products efficiently enough to meet human demands. The productivity of modern agriculture has also been greatly assisted through fertilizers, pesticides and irrigation. Unfortunately pesticides, when used unwisely, have raised the ire of society. Pests also develop resistance to pesticides unless complex resistance strategies are employed. In more recent years agriculturalists have begun to develop IPM strategies using a range of management tools including cultural, chemical and genetic agents.

Permaculture, biodynamic and organic farming systems are often proposed as the directions modern agriculture should take. There is strong interest in these systems, especially organic farming. However, in total they only currently represent around 0.8% of the total area farmed in Australia (Twyford-Jones & Doolan 1998). This sector makes a valuable contribution, albeit small (around $100 million annually), to Australia's rural production. It is estimated that organic food accounts for about 1% of overall world food sales (Twyford-Jones & Doolan 1998). While organic farming clearly has a role in agricultural production and will continue to capture important niche and specialist markets, its ability to meet the mainstream requirements of food and fiber has to be seriously questioned.

Consumers reading the popular press may feel organic systems provide a simple answer to their perceptions of the problems of modern agriculture. Unfortunately, organic farming struggles with quality, supply, production cost and pricing issues. Anyone familiar with farming understands the difficulties faced by organic and traditional farmers. Many of the practices adopted by organic farmers to obviate the use of pesticides and fertilizers are not conducive to high productivity nor are they always kind to natural resources. Delaying planting dates to allow better weed control can result in significant yield reductions which increase the per unit cost of the product. The use of grazing animals to remove weeds ahead of crop plantings can dramatically increase soil compaction especially when compared to controlled traffic techniques of modern agriculture. The use of cultivation instead of adopting minimum tillage systems can also be questioned.

While most modern organic pesticides are not accepted in organic farming, other pesticides are used including pyrethrum, sulphur treatments and topical, so-called "biological" sprays including *Bacillus thuringiensis* (Bt), e.g. Dipel and virus preparations. Bt sprays have essentially the same active protein as genetically modified insect resistant cotton plants.

Whatever system of production we seek, the real answer for long term management of agricultural systems lies with integrated approaches that do not rely on any one control agent. The use of genetically modified organisms offers an exciting tool in an integrated approach.

Conclusions

Gene technology is playing an important role in modern society. From manufacturing and human health through to agriculture, genetic engineering is providing opportunities and challenges to society. Gene technology in cotton has demonstrated outstanding benefits to Australian cotton producers. Reductions in pesticide use, reduced resistance pressure on insecticides, reduced environmental impacts and greater utilization of integrated pest management systems have been the main benefits. In most cases these benefits have come at about a neutral cost from traditional cotton systems. Cotton growers believe this technology will reduce production costs with flow on benefits to consumers. Australian cotton producers envy their American counterparts who are paying significantly less for Bt cotton and look forward to removing this pricing anomaly.

Trials with two-Bt gene cotton in 1998/99 showed significant benefits over conventional and single-Bt cotton under field conditions.

Greater insect resistance, improved disease resistance, improvements to fiber characteristics and greater water use efficiency are some of the future benefits this technology offers.

Most importantly gene technology allows the development of better IPM systems which offer the best directions for future food and fiber production for modern society.

To be accepted more widely, the benefits of GMO technology in agriculture must be demonstrated to the consumer. The wide use of biotechnology and recombinant DNA in the pharmaceutical industry has generally been accepted through the obvious link to human health. The irony in the debate is that if consumers really wanted to help the environment, they should embrace GMO's and work towards the best management of them. The mistrust of multinational companies, the failure to understand modern food and fiber production issues and the delusion that everything natural has to be best add to the difficulties facing GMO's. Clearly the efforts that went into the science now have to go into public understanding and dialogue.

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