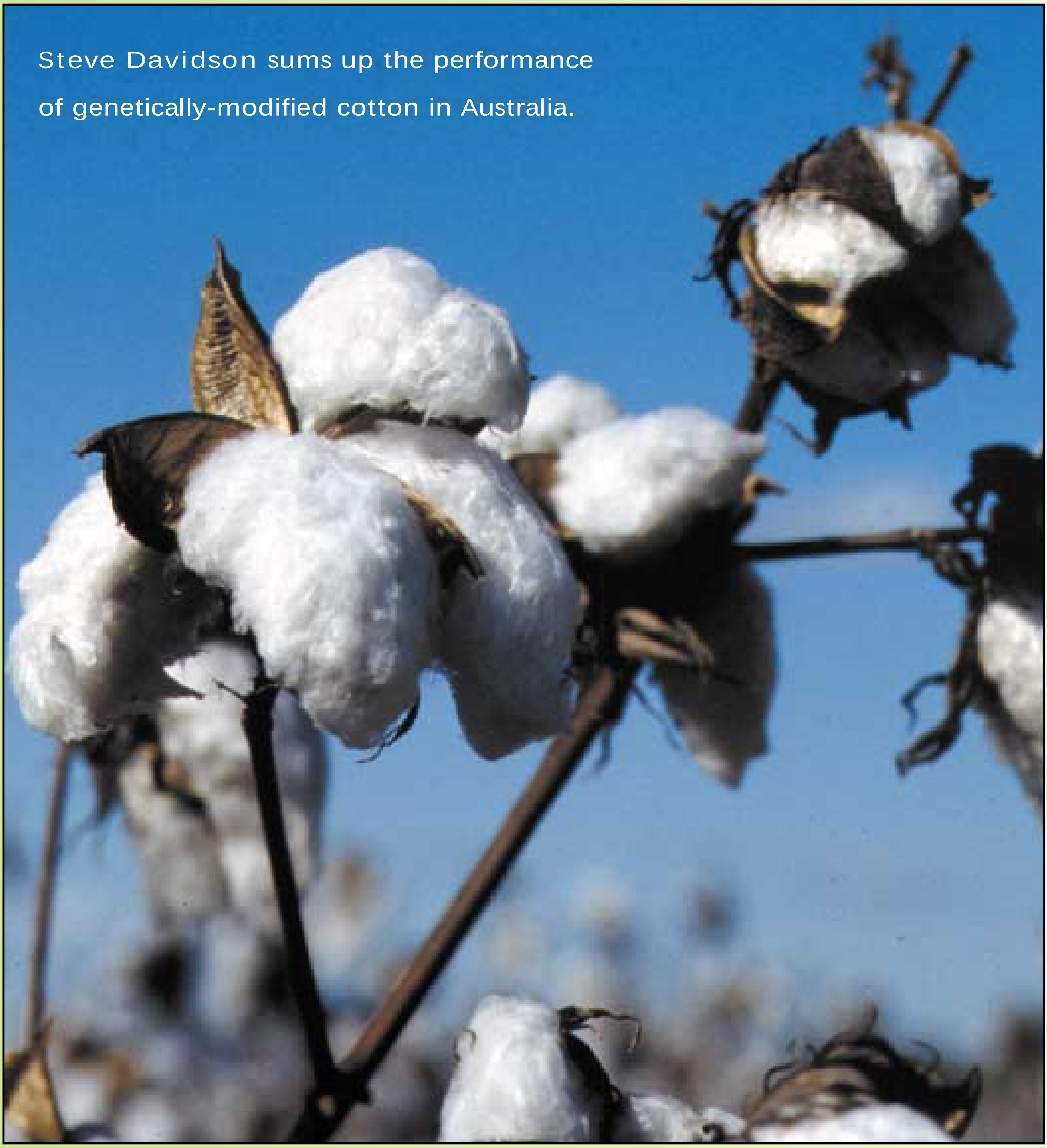
Biotech cotton a budding field

Steve Davidson sums up the performance of genetically-modified cotton in Australia.



In 1996, the first commercial genetically-modified crop was released in Australia. The crop was Ingard® cotton, a transgenic variety containing a gene from the soil bacterium, *Bacillus thuringiensis* or Bt, a microbe long used as a biopesticide in horticulture. Seven years on, it seems that, apart from the cotton's creator, the environment is its main beneficiary.

Ingard was developed from traditional high-yielding CSIRO cotton varieties in a partnership involving CSIRO, Cotton Seed Distributors and Monsanto.

The intention was to lessen pesticide use on Australian cotton farms, which are plagued by the cotton bollworm and the native bollworm (*Helicoverpa* species).

Similar caterpillars bother cotton crops in the United States, but Australian infestations are relatively extreme. Here, cotton growers might apply pesticides 12–14 times a season, at great cost, compared with two to five times in the US.

The engineered bacterial gene, *Cry1Ac*, causes cotton plants to produce an insecticidal protein that damages the gut of caterpillar pests, thereby reducing the need for pesticide applications.

How has it performed?

In the first year of its release, 30 000 hectares – 8% of Australia's cotton crop – was planted to Ingard. Today, some 50% of our cotton fields grow genetically-modified varieties: either Ingard, or the herbicide-tolerant variety, Roundup Ready®.

The performance of Ingard cotton was reviewed last year by Dr Danny Llewellyn and Dr TJ Higgins of CSIRO Plant Industry, and Dr Gary Fitt of CSIRO Entomology, chief executive officer of the Australian Cotton CRC in Narrabri, New South Wales. They concluded that the environmental benefits of the genetically-modified cotton were beyond question.

Monitoring by the Cotton Research and Development Corporation has shown that Ingard cotton requires 40–60% less pesticide than conventional cotton crops.

The greatest reductions have been in the use of endosulfan, carbamate and synthetic pyrethroid insecticides.

Endosulfan is a concern as a residue risk in export beef and is toxic to fish, while carbamates and synthetic pyrethroids are disruptive to beneficial insects.

As a bonus, the reduction in pesticide use, and the associated increase in helpful insects, enables growers to apply a suite of pest control measures known collectively as 'integrated pest management'.

The cost savings relating to Ingard, however, are not quite so straightforward: they are counteracted by the licence fee charged by Monsanto, owner of the Bt gene.

While the savings in pesticide costs may reach $180 a hectare, the licence fee is $155 a hectare. So the economic outcome of using Ingard could range from a net gain of $50 a hectare, to a net loss, depending on infestation levels and crop management efficiency.

But these economic analyses fail to address such intangibles as environmental benefits and ecological sustainability.

They undersell the true value of Bt cotton, as its real positive outcomes are still seen as environmental. Growers cite 'protection of the environment' as their main reason for choosing the genetically-modified crop.

Pre-empting resistance

From the outset, there has been concern that bollworms could develop resistance to Bt cotton.

Helicoverpa armigera has developed some degree of resistance to just about every chemical used against it, and both *H. armigera* and *H. punctigera* – Australia's worst cotton pests – are 10 times more tolerant of the *Cry1Ac* protein in Ingard cotton than the main target species in the US, *H. virescens*.

For these reasons, scientists and the cotton industry have developed a resistance-management strategy that centres on the compulsory planting of specified 'refugia', or areas of conventional cotton or other crops adjacent to Bt crops.

As moths from the refuge crop disperse and mate with moths in the genetically-modified crop, they dilute the resistance genes that may have been selected by the Bt toxin. Effective refugia ensure that a mating between two resistant survivors from a transgenic crop is extremely unlikely.

Other features of the strategy, directed specifically at *H. armigera*, include: a defined planting window for Ingard cotton to avoid late-planted crops that could be exposed to abundant bollworm, mandatory cultivation of the crop to destroy most over-wintering pupae, defined spray thresholds, and monitoring of Bt resistance in moth populations.

Ultimately though, cottons with a single Bt gene will remain vulnerable to resistance in the target insect and cotton varieties, with two insecticidal genes considered essential in the long term.

A new variety released last year, Bollgard II®, employs just this strategy, containing an additional *Cry2Ab* gene

Dr Danny Llewellyn of CSIRO Plant Industry says the genetic modification of cotton plants has made a positive contribution to environmental sustainability and, in the future, the approach should lead to higher-quality cotton fibres and oil.

As controls tighten, biotech fears ease

GENE TECHNOLOGY is a controversial issue and the Australian community has strong attitudes both for and against. This is probably fuelled by what has been called a 'war of misinformation between interest groups'.

Craig Cormick of the government agency Biotechnology Australia says that for every industry or research group that claims genetically-modified (GM) foods could feed the world, there is another group claiming they will devastate the environment.

'In truth, both are wild exaggerations,' Cormick says.

'Among the most frequent myths about GM technology have been claims that GM tomatoes contained fish genes, that GM corn killed Monarch butterflies in the US, or that GM crops are the only way to feed the developing world.'

Cormick says the most recent survey, conducted for the agency in 2002, showed that in the past 12 months perceptions that the risks of GM foods and crops outweighed the benefits had not changed much, but there had been a significant increase in those who see benefits outweighing risks.

Agricultural applications of biotechnology, particularly those that result in more pest-resistant plants, are generally thought to be a good idea.

Overall, 54% of Australians did not feel confident that GM foods were safe for human consumption.

Of course, cotton is essentially a fibre crop, which is less likely to concern consumers than food, and an earlier Biotechnology Australia survey also showed that agricultural applications of biotechnology, particularly those that resulted in more pest-resistant plants, were generally thought to be a good idea. This is probably largely due to the high media profile of Ingard cotton.

Also, CSIRO was considered one of the more reliable sources of information on biotechnology.

People often express concern that biotechnology is 'out of control' and this pressure of public opinion no doubt contributed to the switch from a partly voluntary system of gene technology regulation to a tough new system of regulation, the Gene Technology Act 2000.

This Act has impressive statutory powers, including seizure and penalties, to ensure compliance by all parties involved in biotechnology research, development and commercialisation.

It gives Australia the most strict and open system of regulation of any country in the world, requiring the disclosure of all details including the exact coordinates of any field release of GM crops.

Opponents of biotechnology complain that people, including some scientists, who disagree with GM proponents are ridiculed or marginalised.

Perhaps the companies involved in the technology need to take community fears and views more seriously to avoid further consumer backlash.

Reports that Bt crops can have deleterious effects on soil microbes will perhaps be a test of the attitude of those in the biotechnology industry. Will they respond with reason or recrimination?

More information can be found on the Biotechnology Australia website at www.biotechnology.gov.au/

The engineered bacterial gene, *Cry1Ac*, causes cotton plants to produce an insecticidal protein that damages the gut of caterpillar pests. Growers can halve their pesticide use by planting cotton varieties containing the gene.

developed by Monsanto and introduced to Australian cotton varieties by CSIRO.

Early trials with Bollgard II have been promising, with much better insect control than Ingard. Further reductions in pesticide applications should ensue as Bollgard II is adopted and, importantly, with less risk of resistance. Ingard cotton will be phased out, probably by 2004–05.

Future modifications

The genetic modification of cotton is set to reach far beyond the realm of pesticide resistance.

A herbicide tolerant strain of cotton has been rapidly adopted since its release in 2000 but, like Bt cotton, it is not a 'magic bullet' and it has been incorporated into an integrated weed management program.

CSIRO Plant Industry is involved in a project aimed at modifying the plant's production of an enzyme that controls sugar flow into cotton fibres. The idea is to trick the plant into making longer fibres.

According to press reports, Chinese researchers have introduced a rabbit fur gene into cotton, making the fibres longer and more lustrous.

Overseas attempts to produce plants that grow blue or black cotton fibres, however, using genes for pigment production from bacteria, have proved unsuccessful.

Plant Industry scientists are also involved in the development of genetically modified cotton oils. Although a mere by-product of cotton fibre production, cottonseed oil is Australia's major oilseed crop.

Genetic modification to shut down some of the enzymes involved in desaturation of the oil in cotton seeds has allowed the CSIRO scientists to produce two cotton varieties that give different types of oils with specific food uses. Field-testing should begin this year as a precursor to food-use evaluations.

Cotton researchers are also keen to produce DNA markers to assist plant breeders.

These molecular markers identify regions of DNA associated with a particular characteristic of a plant, for example tolerance to cotton diseases such a wilts, cotton bunchytop and alternaria. They can quickly tell scientists that a particular trait is present in an individual plant, thereby speeding the process of breeding improved lines.

Unfortunately, this development of markers is proving difficult in cotton because in the course of domestication and cultivation, cotton has passed through very narrow genetic bottlenecks, making all varieties appear similar, at least at the DNA level.

Nonetheless the prize is so attractive that international efforts to develop markers linked to disease tolerance continue.

More about genetically-modified cotton

Llewellyn DJ and Higgins TJV (2002) Future Biotechnologies. In *Proceedings, 11th Australian Cotton Conference*, Brisbane, Queensland, 13–15 August 2002, pp. 757–767.

Fitt GP (in press) Deployment and impact of transgenic Bt cottons in Australia. In *Global Impacts of Biotechnology*, Kalaitzandonakes N (Ed.) Kluwer.

Abstract: The cotton variety, Ingard®, carrying a Bt bacterial gene that protects the plant from bollworm pests, was the first genetically modified crop released commercially in Australia. It has reduced pesticide applications by an average of 50% compared to conventional crops and allowed two-to-three fold increases in beneficial insects. The industry is using a pre-emptive strategy to counter the risk of resistance to the Bt protein developing in bollworms. This includes compulsory planting of refugia crops to reduce selection pressure. A new more effective GM variety, Bollgard II®, with two Bt genes, has made its debut, further reducing the risk of resistance.

Keywords: cotton, Bt cotton, genetically modified organisms (GMOs), pesticide resistance, Bollgard II cotton.