Spotlight.

ON COTTON R&D

Summer 2015-16

Sowing the seeds of success: CRDC achieves 25-year milestone

Australian Government
Cotton Research and Development Corporation

In the Spotlight

It's been 25 years since CRDC was formed.

The organisation has grown from three staff members in its first year with Executive Director Ralph Shulze and two administrative assistants to today, a team of 14, led by Executive Director Bruce Finney and Chair Dr Mary Corbett. CRDC has invested $280 million on behalf of Australian cotton growers and the Australian Government into cotton research, development and extension during this time. A special feature on CRDC's 25 years starts of on Page 8 of this edition of *Spotlight*.

Pictured are CRDC's current staff (back row left to right) R&D Manager Jane Trindall; General Manager Business and Finance Graeme Tolson; Accountant Emily Luff; Executive Assistant Dianne Purcell; CottonInfo Program Manager Warwick Waters; and Communications Manager Ruth Redfern.
At front: Executive Director Bruce Finney; Clarity Assistant Marg Wheeler; Project Admin Assistant Megan Baker; Assistant Accountant Ginny Taylor; Project Admin Assistant Amy Withington; General Manager Research and Development Investment, Ian Taylor. Absent: R&D Managers Allan Williams and Susan Maas.

Summer 15-16

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Cotton Research and Development Corporation
ABN: 71 054 238 316
Our vision: A globally competitive and responsible cotton industry.
Our mission: To invest in RD&E for the world-leading Australian cotton industry.

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ON THE COVER
Research spanning three generations: John Seery grew his first crop of cotton in the Gwydir Valley in 1978, and his son Steve along with grandsons Thomas and Lucas continue the tradition.

Cotton News

Features

Fast Facts

25

the number of years CRDC has been operating.

$280 million

CRDC's investment in cotton RD&E on behalf of Australia's cotton growers and the Government over the past 25 years.

2100

the number of research projects CRDC has invested in since 1990.

$5 billion

the estimated return on investment at 2002 from CRDC's early investment in plant breeding.

$30 billion

the value of cotton's exports over 25 years.

Vale: Dr Ian Rochester

THE cotton industry has been greatly saddened by the passing of Narrabri-based scientist, Dr Ian Rochester (Rocky), who passed away in September. Rocky had a long and distinguished career as a cotton nutrition scientist with CSIRO, based at the Australian Cotton Research Institute near Narrabri.

Over this time he evolved a broad research program to understand and improve nutrition of cotton through innovative cropping. Rocky's pioneering work on nitrogen mineralisation in the soil demonstrated the importance of different forms of nitrogen fertiliser and underpins our current understanding of nutrition in cotton production systems.

His research evolved to include improved use of soil and petiole diagnostic tests, development of NutriLOGIC to support growers with interpretation of nutritional tests and pioneering research assessing nitrogen use efficiency.

Rocky's initial research identified that approximately a third of the growers assessed were over fertilising for nitrogen. Subsequent work showed that up to 50 percent of nitrogen fertiliser applied to cotton crops can be lost, including a significant portion through nitrous oxide emissions. Through the development of innovative cotton cropping systems incorporating a legume phase, Rocky's research demonstrated scope for substantial reductions in N fertiliser inputs into Australian cotton fields, also minimising greenhouse gas emissions – without reducing yields.

Rocky's work has had a hugely positive impact on the Australian cotton industry, strongly influencing both grower practice and the debate around optimising nutrition to maximise yield and minimise losses and emissions.

In recent years, Rocky had been working towards retirement on the coast, publishing his most recent research and starting preliminary new research on the links between cotton nutrition and genetics to ensure an enduring and fruitful legacy for the future.

CRDC Executive Director Bruce Finney paid tribute to Rocky: "Rocky was one of the founding members of the Australian cotton research community and had been part of the CRDC research fraternity for more than two decades.

"Rocky was the quintessential cotton researcher: a deep thinker, methodical and committed to his research, unwavering in the conviction of his findings and seeking to make a difference for the cotton industry. Combined with a laconic, sincere and down to earth personality he endeared himself to those that had the privilege to meet and work with him.

"His passing is a great loss to the cotton industry and we express our condolences to his family and colleagues at ACRI."

CRDC supporting rural women

CRDC hosted a group of bright, enthusiastic future industry leaders at the RIRDC Rural Women's Award dinner in Canberra in September.

Long term CRDC staff member Dianne Purcell was joined by CRDC-sponsored Horizon Scholars Kirsty McCormack, Jessica Kirkpatrick, Camilla a'Beckett and Emily Miller; Wincott's Lauryn Riordan (a 2014 Future Cotton Leader, supported by CRDC and Cotton Australia) and Belinda Mulcahy; and well known industry communicator and recent industry-sponsored graduate of the Australian Rural Leadership Program, Brooke Summers.

CRDC Executive Director Bruce Finney said CRDC has been a long-time supporter of projects and initiatives designed to support rural women, such as the RIRDC Rural Women's Award, as part of the suite of initiatives that CRDC invests in as part of its 'people' program.

"We support a wide range of programs that help to develop our industry's people – from Horizon Scholars and Future Cotton Leaders to the Australian Rural Leadership Program and RIRDC's Rural Women's Award," Bruce said.

"This year, we were able to bring together a number of women we support through these programs for the Rural Women's Award dinner: helping to encourage future participation in this great program, which has been supporting women in rural industries for the past 15 years.

"From the feedback we've received, the women in attendance on behalf of CRDC were very inspired by the outstanding female leadership shown by this year's RIRDC finalists," Bruce said.

CRDC's Di Purcell with Horizon scholars Emily Miller, Kirsty McCormack, Jessica Kirkpatrick and Camilla a'Beckett.

The 2015 national recipient of the RIRDC Rural Women's Award was Sarah Powell, part of a family-run mixed-farming business at Wharminda on the Eyre Peninsula. Sarah is utilising the potential of local sporting clubs as a mechanism to build future leaders, which she believes is core to keeping regions sustainable. She believes these community groups are an important vehicle for young people and women to gain essential skills and confidence and ultimately increase their community participation.

"Opportunities to network with, be inspired by, and to develop into such leaders are invaluable, which is why CRDC continues to support the RIRDC award, and all the other people development programs," Bruce said.

Horizon Scholar Jessica Kirkpatrick summed up the evening, saying the opportunity to attend the Award was "motivating and inspiring – a great celebration of women in agriculture".

For more information on CRDC's range of people programs, please visit www.crdc.com.au. For more information on the RIRDC Rural Women's Award, please visit www.rirdc.gov.au.

CRDC researcher a leader in innovation

Nancy was a finalist in the Environment, Agriculture and Food category of The Australian Innovation Challenge

CRDC-funded researcher and CSIRO entomologist Nancy Schellhorn was a finalist in The Australian Innovation Challenge for her project *Capturing Production-Based Ecosystem Services*.

Nancy's research involves using economic and ecological arguments grounded in science to convince farmers to conserve or reintroduce native habitat on their land to sustain organisms, such as beneficial insects and spiders which provide natural pest control. The goal is to reduce the amount of pesticides used on farms.

"The research is about blurring the line between natural and production land. We can see these win-win situations," Nancy told *The Australian*.

Nancy was a finalist in the Environment, Agriculture and Food category, which has a $5000 prize. This category encompasses innovation to tackle problems and challenges in pollution control, biodiversity, conservation, land degradation, water conservation and quality, climate variability and extreme events.

Updated resistance toolkit: stop weeds fighting back

THERE'S now an easier to use tool to tackle glyphosate resistance in the paddock and anywhere else herbicide resistance might be brewing in a farm's local weed population.

Herbicide resistant weeds are the terrorists of the plant world, diabolically undermining our established glyphosate-reliant cropping systems.

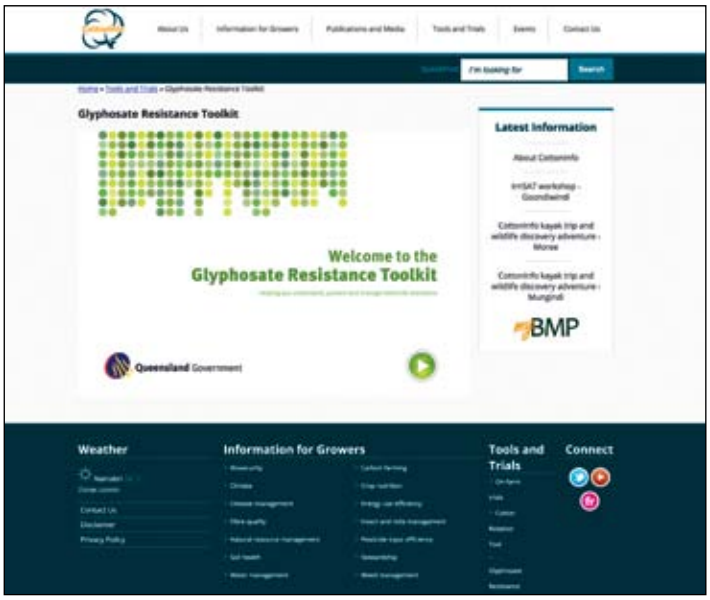
The problem of glyphosate resistance is rapidly getting worse, with new weed species such as sweet summer grass (*Brachiaria eruciformis*) adding to an already long list of plants that have developed a tolerance for glyphosate including awnless barnyard grass, fleabane, sowthistle, windmill grass and annual ryegrass.

Weeds researcher Dr David Thornby (formerly of DAF QLD) says a failure to slow the development of herbicide resistance will see crop management costs rise and cause ongoing issues for farm managers.

"Weeds are survivors with an innate ability to evolve to cope with herbicide attack. Poor weed management strategies with an over reliance on glyphosate for weed control, will inevitably result in more species developing resistance," David said.

David and his former colleague at DAF QLD Dr Jeff Werth have updated the Glyphosate Resistance Risk Assessment Toolkit, originally developed by the pair in 2011, making it much easier for growers to use.

"This tool enables farmers and other land managers to precisely calculate the risk of glyphosate resistance in any given paddock," David said.



"With the new design, users don't need to be experts in weed control to interpret the results. The toolkit also guides land managers through strategies that will significantly delay the spread of herbicide resistance.

"It's much easier now for farmers to compare the results of each paddock assessment. If you have one glyphosate resistant species, you don't want to make life harder by allowing other weed species to develop resistance as well."

CRDC, meanwhile, has released the Australian cotton industry's first *Herbicide Resistance Management Strategy* (HRMS), a tool for managing the risk of herbicide resistance in irrigated and dryland farming systems.

The HRMS provides industry wide support for growers and agronomists to make changes in weed control practices that will slow the evolution of resistance.

To read the HRMS guidelines, visit: www.crdc.com.au/publications/herbicide-resistance-management-strategy

For the Glyphosate Resistance Toolkit, visit: www.cottoninfo.com.au/resistance-toolkit

SAVE THE DATE: Nitrogen Tour

Responding to industry requests, planning is underway to bring growers and consultants the CottonInfo Nitrogen Research Tour in early 2016. The tour will bring a team of leading cotton industry researchers on-farm to meet with growers from Central QLD to Southern NSW, providing the latest research and findings in nitrogen and soil health. The tour will take place from Monday 8 to Friday 12 February. For details, including times, locations and confirmed speakers, visit www.cottoninfo.com.au/events/nitrogen-research-tour-central-qld-southern-nsw.

The impact of rotations

ROTATION crops are an important consideration for all cotton farmers, with a range of considerations: weeds, insect hosts, diseases, water use and soil structure. Choosing the right rotation for your system can be complex, which is why CRDC and the former Cotton CRC originally established the Cotton Rotation Tool.

The tool allows growers to compare the advantages and disadvantages of different rotation crops in relation to the subsequent cotton crop. It covers sunflowers, soybeans, maize, sorghum, mung beans, pigeon peas, chickpeas, faba beans, lucerne, canola, safflower and more. It provides information on the impact a rotation has on the cotton crop, as well as any interactions that growers may need to be aware of in terms of insect dynamics when a particular rotation crop is included in the farming system.

The Tool has found a new online home at CottonInfo.
To access it, visit: www.cottoninfo.com.au/cotton-rotation-tool.

Lowbidgee grower joins Trust

COTTON grower Adam Harris has been selected as the 2015 cotton industry participant in the Peter Cullen Water and Environmental Trust leadership program, supported by CRDC and Cotton Australia.

Hailing from the Lowbidgee (Lower Murrumbidgee) region of NSW, with his family he operates 30,000 hectares of dryland and irrigated cropping country and chairs a local body representing farmers and graziers. Adam also sits on a committee of NSW Water which contributes to operating decisions for the Murrumbidgee River.

He will join 14 others in the 'Science to Policy' trust program, which focuses on leadership and communication skills specifically aimed at bringing about positive change in water and catchment management in Australia. His fellow participants are all actively involved in water systems management - be it river or catchment science or policy, rural water or environment. On graduation Adam will join the alumni of cotton industry Trust fellows, including Juanita Hamparsum, Susan Madden, Brendon Warnock, Brendan Barry, Jane Trindall and Luke Stower.

For more
Peter Cullen Trust
e www.petercullentrust.com.au

New CottonInfo RDO for Darling Downs

A NEW Regional Development Officer (RDO), Annabel Twine, joined the CottonInfo team in November to bring the latest research outcomes and findings direct to cotton growers, consultants and the wider cotton industry in the Darling Downs.

Annabel brings extensive experience to the CottonInfo team, having worked in agriculture for 20 years, including six years with Queensland Cotton and 13 years with Bayer CropScience covering the Downs and the Macintyre and Balonne valleys.

Annabel already has a strong relationship with growers, consultants and resellers in the area, having developed and delivered training on product use and run on-farm demonstration trials, and will bring these skills into the RDO role with CottonInfo.

"Annabel brings a passion for agriculture, knowledge of the cotton industry and existing networks to the role of regional development officer," said Cotton Seed Distributors (CSD) General Manager - Development and Communications Philip Armytage. CSD is one of the three partners in the CottonInfo venture, along with CRDC and Cotton Australia.

"Annabel's role will be to connect The Downs growers with relevant industry research and best practice, supporting them to continue to increase their farm productivity.

"On behalf of the CottonInfo joint venture partners, we welcome Annabel to the team and also thank former Darling Downs RDO John Smith for his work in this role since CottonInfo's inception."

Annabel joins the 20-strong CottonInfo team, which includes her fellow on-the-ground RDOs across the cotton growing valleys, researchers who are technical specialists in their specific fields and *my*BMP best management practice support staff.

For more
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Science on the agenda

THE open sharing of ideas and the discussion of challenges are just two of the positive outcomes from this year's Australian Cotton Research Conference according to committee chair and well-known cotton industry scientist Paul Grundy.

Held at the University of Southern Queensland in August, the conference has been hailed as the best yet, with more than 200 researchers converging on Toowoomba to present or hear the latest research. Some 130 presentations were given over three very full days.

"The conference is also a fantastic opportunity to showcase some of the research areas that are not production-oriented and consequently don't get regularly discussed at industry events," Paul said.

"Importantly the event serves to recognise people's achievements at a peer level and promote the contribution that research makes to the cotton industry.

"We find that it's an open ground for information sharing, collaboration and ideas for new research.

"It's not often that researchers from all disciplines within the cotton industry have the opportunity to come together to discuss their work and hear about the work of others."

CRDC is the founding sponsor of the conference, which is held by the Australian Association of Cotton Scientists. Thanking attendees and the committee, Paul said it is no small task to offer so many presentations across so many fields of study, and the feedback had been tremendous.

For more information, or to download the proceedings from the conference visit www.cottonresearch.org.

2015: 25 YEARS OF RESEARCH, DEVELOPMENT & EXTENSION

2015 marks 25 years of the Cotton Research and Development Corporation (CRDC). In this special edition of Spotlight, we take a look back at 25 years of delivering research, development and extension (RD&E) outcomes for the benefit of Australia's cotton growers, the cotton industry and the wider community.

Today, the Australian cotton industry is one of the success stories of Australian agriculture.

Australian cotton is the highest-yielding, finest, cleanest and greenest cotton in the world.

We're an industry taking responsibility for ourselves by changing our practices to meet our own expectations and those of contemporary society.

Our best cotton producers now achieve more than two bales of cotton per megalitre of water – almost double the industry average of just a decade ago. Our industry is at the forefront of environmental management systems, climate change preparedness and adaptation.

It's an extraordinary story of achievement, thanks primarily to the continued support of the industry and the Australian Government to the value of RD&E.

It has, and continues to be, a combined and collaborative effort. CRDC invests in RD&E on behalf of cotton growers and the Australian Government, with the oversight of industry bodies – originally the Australian Cotton Growers Research Association (ACGRA) and now Cotton Australia – and the research prowess of our many different research partners.

We should always give thanks to our industry pioneers for their vision and determination not only to grow cotton, but to establish an industry supported by its own R&D. In this spirit the ACGRA was established in 1972 with a voluntary R&D levy of $0.25 per bale. This step was recognition of the importance of collective funding for industry R&D. Our pioneers were also strong advocates for Australian Government matching grower financial contributions.

CRDC was established in 1990 under the *Primary Industries Research and Development Act 1989* (PIRD Act). It was established by the Australian Government to work with industry to invest in RD&E for a more profitable, sustainable and dynamic cotton industry – at a time when the cotton industry was facing significant societal pressure around its environmental impacts.

Throughout the next 25 years, CRDC's strategic leadership and collaboration in RD&E investment has become a driving force behind the industry's continuous improvement and transformation.

Over this time, CRDC has invested more than $280 million into RD&E on behalf of the industry, delivering billions of dollars in benefit back to Australian cotton growers on their farms. One project alone – CRDC's investment in plant breeding – is estimated to have singularly contributed $5 billion to the industry and the Australian agricultural economy.

In terms of the impact of R&D, our world leading cotton yields and quality are easy to see and quantify. Efficiency gains in water use and reductions in pesticide use are also evident.

But arguably, cotton production would not have been possible for the last 20 years - during which time growers have collectively contributed to producing more than $27 billion in exports - if it wasn't for R&D and the industry's commitment to improving its practices in controlling insects and managing diseases such as Fusarium.

CRDC has managed some 2100 projects over the past 25 years – moving from a responsive approach of specifically addressing the industry issues of the 1990s; to a more proactive approach of collaboratively identifying potential future threats and opportunities and strategically investing in them to ensure the industry's continued success.

These are just some of cotton's RD&E achievements. **Over the coming pages, you will find our list: what we believe are the 25 major achievements in cotton RD&E over the past 25 years.**

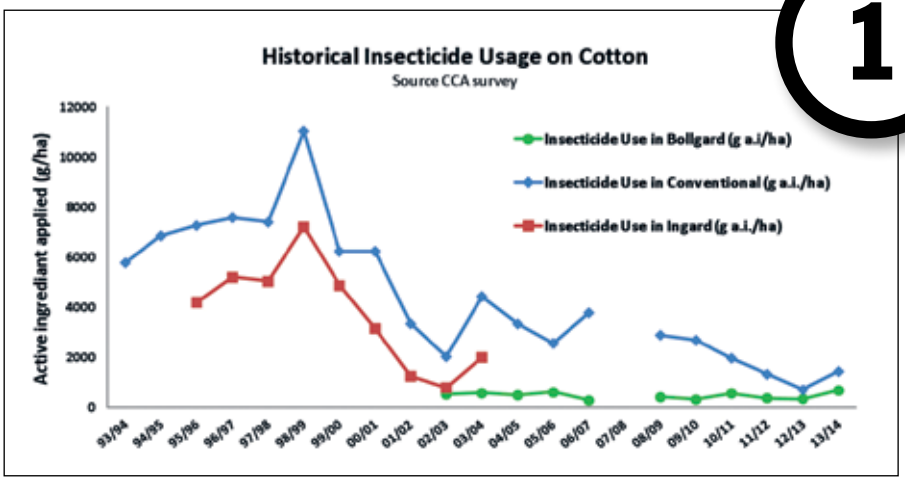
These are 25 key areas in which the co-investment into RD&E by cotton growers and the Australian Government has significantly benefited our industry – like our strong improvements in water use efficiency; our efforts to improve environmental performance; our contributions to building the capacity of the industry's most important resource, its people; and our contribution to the industry's best management practices program; all examples where investment in RD&E has helped to deliver highly valuable outcomes.

In celebrating the successes born from RD&E investment, we wish to acknowledge that it has been achieved due to the contributions of many people. We are proud to have worked with so many inspirational people – within our own team, and across the cotton research and cotton growing communities. We thank all who have been part of CRDC's journey to date.

Integrated pest management: overcoming industry's greatest threat

1

Managing pests in a sustainable manner without building resistance to control measures has been the greatest challenge for Australian cotton growers and CRDC RD&E over the last 25 years.



Based on data from the annual Crop Consultants Australia industry audit.

Following a series of pesticide crises through to the late 1990s, it was through RD&E that integrated pest management (IPM) became one of the greatest achievements of the Australian cotton industry.

IPM refers to the use of various sustainable methods to control pests and as a result of its broad adoption, the industry enjoys low levels of insecticide resistance, less dependence on insecticides, significantly improved environmental outcomes and sustainability, increasing average yields, and ever widening areas of production.

However, the situation was vastly different when CRDC commenced in 1990. With escalating insect populations, increasing resistance to insecticides and public pressure to reduce their use the industry was urgently seeking solutions. The collapse of cotton production in the Ord River system of WA in the '70s due to insect pressure stood as a dire warning.

CSIRO Senior Principal Research Scientist Dr Lewis Wilson began working in cotton entomology in 1985 when pest control relied largely on broad spectrum organochlorines, until resistance began to develop in *Helicoverpa armigera*.

"Pyrethroids became available in the late 1970s and were hailed as a saviour, however by the early 1980s overuse had rapidly selected for resistance in *H. armigera* and secondary pests such as spider mites and aphids had emerged due to inadvertent destruction of their natural enemies," Lewis said.

"By 1990 control of *H. armigera* was increasingly difficult as resistance to conventional broad spectrum insecticides had crept higher, despite industry having developed and utilised an insecticide resistance management strategy (IRMS) since 1983-84."

In its first year, CRDC's RD&E investment directed to 'Crop protection' and 'Improved environmental outcomes' received 33 percent of funding respectively. With research into new cultivars and genetic modification at 17 percent, this equated to 83 percent of the first budget being committed to improving crop protection while improving associated environmental outcomes, and creating cultivars to (among other characteristics) control pests, in particular Helicoverpa.

In subsequent years, research continued into conservation and exploitation of natural predators, better understanding of pest ecology, non-chemical pest control and studying the ability of cotton plants to compensate for pest damage. Pest surveys and resistance monitoring also became part of the agenda.

Extension of IPM R&D outcomes to growers was a high priority. In 1992 CRDC employed Bruce Pyke to ensure research results were communicated to growers and consultants. Industry Development Officers were appointed in growing valleys with support from CRDC, NSW and QLD state departments of agriculture. These investments resulted in the publication of IPM technical documents, field days, seminars and workshops such as the ground-breaking IPM Short Course for growers and the release of the LepTon test kit meant growers and consultants could differentiate between insecticide resistant *H. armigera* and susceptible *H. punctigera* which improved efficiency and reduced the risk of spray failure. CRDC began funding the monitoring of commercial crops across all regions.

In 1995-96 the development and field testing of the EntomoLOGIC program, supported by CRDC was a breakthrough in IPM. It demonstrated that inputs could be reduced if effort is put into monitoring the crop for pests and beneficials and the recommended pest thresholds applied rigorously.

In 1997 the first transgenic cotton Ingard was introduced, along with a pre-emptive, comprehensive Resistance Management Plan (RMP), giving the first indication of how an IPM system could be developed that used natural enemies to reduce pest abundance and the need to spray. CRDC also produced the *Cotton Pest and Beneficial Guide* and SPRAYpak which focused on IPM and farmer responsibilities regarding pesticide use.

However the 1998-99 season was extremely difficult for growers. Heavy pest pressure saw control costs escalate

up to $1000/ha, cotton bunchy top (an aphid vectored viral disease) emerged and escalating insecticide resistance threatened to decimate the industry.

"This was the tipping point for IPM adoption with the industry responding to the crisis with renewed interest in, and uptake of, IPM," says Lewis.

The first industry IPM Guidelines were developed with input from growers, consultants, CRDC and researchers Dr Robert Mensah and Lewis, incorporating resistance management. The release of the first effective 'selective' insecticides enabled control of *H. armigera* with less negative effects on natural enemies and allowing for a practical IPM system to work.

Area Wide Management (AWM) groups were set up, providing a strong network for dissemination of information and two-way communication between growers, consultants and researchers. CRDC-funded economic analysis of different pest management approaches with the first AWM group at Boggabilla showed that fields managed with selective insecticides returned greater profit than those managed with less selective insecticides. This finding was hugely influential in convincing economically shrewd cotton growers and consultants to move toward IPM.

Lewis says that by the early 2000s pest management practices had begun to change and insecticide use had declined dramatically (see graph).

The release of Bollgard II in 2003 drastically reduced the number of sprays and relieved pressure on resistance to selective insecticides which had begun to develop. The rapid uptake of Bollgard II provided an ideal platform for IPM. Ironically, the reduction in pesticide use allowed sucking pests to survive and new pests including silverleaf whitefly, mirids, green vegetable bugs, pale cotton stainers and solenopsis mealy bug have become more significant.

RD&E continued to be under taken to respond to these evolving challenges. CRDC began funding further projects to improve sampling strategies and thresholds, understand pest ecology and consider alternative control options without undermining existing IPM strategies for other pests which has seen no increase in pesticide use for sucking pests since the introduction of Bollgard II, 10 years ago, unlike many other countries around the world.

Brendon Warnock has grown cotton on his property east of Narrabri without the use of insecticides through adherence to integrated pest management.

"The Australian cotton industry's ongoing investment in research into pest ecology, management and resistance monitoring, has underpinned development of world leading IPM and IRM/RMP strategies"

"The Australian cotton industry's ongoing investment in research into pest ecology, management and resistance monitoring, has underpinned development of world leading IPM and IRM/RMP strategies," Lewis says.

"It is one of the few industries to successfully integrate IPM, resistance management and RMPs to ensure effective and sustainable pest management."

Investment in plant breeding and biotechnology has positioned the Australian cotton industry as a world leader.

Breeding success

CRDC was a major investor in the CSIRO Plant Breeding Program from 1990 to 2007, investing $46 million on behalf of growers. In 2006-07 CRDC reviewed the strategic direction of its investment in breeding and biotechnology R&D. Concurrently Cotton Breeding Australia (CBA) was formed by CSD and CSIRO to support future breeding and research. CRDC continues to invest in plant breeding and biotechnology research to address issues such as tolerance to a changing climate, input efficiency, stewardship of Bt technology and biosecurity outcomes.

CRDC Executive Director Bruce Finney says the measure of success of CRDC's investment lays in the fact that Australia's plant breeding research program delivered high performing locally adapted varieties.

"Thanks to investment by CRDC in partnership with CSIRO Plant Industry's cotton breeding team and support of CSD, our growers have access to Australian-bred varieties that sit at the top-end of market quality requirements, produce the world's highest yields incorporating genes which resist the crop's number one insect enemy Helicoverpa, and are tolerant to the non-residual herbicide, glyphosate."

In 2005 the CSIRO Cotton Breeding Team was awarded the prestigious 'Australian Government Prize for Rural Innovation'.

"Furthermore, a 2002 study by CIE estimated that the industry's cotton breeding programs had produced an incredible return of more than $5 billion to the Australian cotton industry and the nation since cotton breeding began in 1984," Bruce said.

"To put this in context, the $5 billion return from the breeding program to the nation on its own significantly exceeded the cumulative investment by the Australian Government and all rural industries through the 14 RDCs up to that time."

By 2007, Bollgard II had been released and disease resistance vastly improved, with CSIRO-bred varieties representing 90 percent of the Australian market and Australian-developed germplasm well represented in leading varieties of upland cotton grown around the world.

The beginning

Developing cultivars to suit Australian conditions was a significant part of cotton research programs prior to CRDC, and by 1990 accounted for 70 percent of the crop. CRDC continued support for breeding programs as a core R&D objective to "develop new or improved cultivars", which also meshed with the objectives to investigate non-chemical forms of pest control, in particular for *Helicoverpa armigera*. Crop protection and environmental protection along with plant breeding were far and away CRDC's core objectives.

By 1992-93 trials were showing promise and in 1993-94 the variety CS8S was released, bred specifically for marginal short season areas, as well as Siokra V15 and Sicala V-2 which had improved tolerance to the widespread disease Verticillium wilt.

In 1996-97 Australia's first transgenic varieties with Ingard was trialled with positive but varied results. The industry quickly realised that reliance on one gene could lead to development of Bt resistance in *H. armigera*. Hence CRDC supported research into other potential trans-genes and resistance mechanisms. Projects investigated the mechanisms of resistance, management of Bt cotton and monitoring field populations for resistance.

In the ensuing years, gene technology was used to breed insect and herbicide-resistant cotton varieties in Bollgard II (replacing Ingard) and Roundup Ready Flex traits from Monsanto, now representing more than 95 percent of Australia's crop and resulting in an 89 percent reduction in insecticide use. Building on this work, the incorporation of a third gene to counter helicoverpa resistance will see the commercial release of Bollgard 3 in 2016-17. CRDC continues strategic investment in plant breeding related research, with key areas including yield/quality improvements, drought, climate change and disease tolerance; and water use efficiency.

Taking research to growers

CRDC's first Annual Report said "The Corporation attaches high importance to the transference of technology and intends to build on the successful actions of the 1990-91 research".

3

St George cotton grower Glenn Rogan and Dr Steve Yeates talking cotton at the first Big Day Out at "Keytah" Moree in 2009. CRDC acknowledged the value of bringing researchers to growers and growers learning from growers in developing this industry event.

Today Australian cotton growers are the best in the world, producing more, higher quality cotton in the most sustainable way than any other country.

Since the first annual report 25 years ago CRDC has taken an increasingly pro-active role in bringing research to Australian cotton farms. CRDC's most recent large scale investment in this area is through the industry's CottonInfo team with partners Cotton Seed Distributors and Cotton Australia.

The link between CRDC and extension goes right back to 1991 through supporting extension people and programs to disseminate research knowledge to growers and consultants. Extending research successfully to growers and consultants has always been a key objective of CRDC.

"The uptake of research and technology is a credit to our growers and has led them to be the most successful in the world," CRDC's Bruce Finney said.

"Whether it's knowledge from long-term projects or information needed quickly to respond to an emerging threat or issue, it is uptake by growers that is CRDC's ultimate goal: so they can be as successful and sustainable as possible, which they are and continue to improve on.

"We are pleased to have played a part in this through promoting the swift extension of research into the field, which started in earnest with the employment of Bruce Pyke in 1992 as the 'technology transfer co-ordinator'.

"Bruce Pyke has been widely acknowledged for the impact he had on bringing research to growers over the following 20 years. His passion for research and innovation coupled with his knowledge of entomology made him the perfect fit."

During the 1992-93 season, in conjunction with its partners CRDC supported the creation of cotton-specific regional extension roles and invested in their placement in the Darling Downs, Macquarie Valley and Emerald.

"Within its first year CRDC had instigated a number of workshops to disseminate and discuss the results of research with growers and consultants, such as 'soil management training'," Bruce said.

"We've always supported the Australian Cotton Conference - the place to find research from every aspect of the industry - and it remains a prime industry event for this."

CRDC has also been a steadfast supporter of many industry information manuals, publishing the *Cotton Pest and Beneficials Guide* in 1995, the *CRDC Handbook*, dryland cotton growing guide and a manual for new growers. It now supports flagship publications such as *The Cotton Production Manual* and the *Cotton Pest Management Guide* in collaboration with CottonInfo.

CRDC is also a great believer in the value of growers learning from growers. The Big Day Out was initiated by CRDC in 2009, so growers could visit "Keytah", managed by the recipient of the Cotton Industry Awards' Innovator of the Year, to share the knowledge among other growers. Research tours have formed part of a successful extension strategy, with this year's widely acclaimed Irrigation Technology Tour a prime example.

The success of grower uptake as a result of effective extension is evident from grower surveys and assessments such as the 2012 Environmental Assessment which showed research is being applied in the field and that it is working to make our growers and consultants the most efficient and sustainable in the world.

To promote the best use of research resources and create a first-class environment for its researchers, CRDC has maintained its role as an ardent instigator, supporter and investor in infrastructure, programs and initiatives such as the Cotton Co-operative Research Centres.

Creating collaboration

Upon formation, CRDC allocated nearly $1 million to upgrade the then Narrabri Agricultural Research Station (now the Australian Cotton Research Institute) which was a large investment at the time, when CRDC's entire budget was around $3 million. During those early years CRDC sought to improve research and ramp up capability, and funded the purchase of ginning equipment and machinery for ACRI and for trials in Queensland. Investment continued at the shared research facility with upgrades to the plant breeding facilities, computer systems, experimental equipment, expansion of facilities for plant drying and pesticide application research.

"CRDC believed that the complex, long-term issues of sustainability facing the industry would be best resolved through co-operative research projects" - this mantra from 1991 was realised through the original submission to the federal government for the first Cotton Co-operative Research Centre being initiated by CRDC, which received resounding support from all sectors of the industry. The CRC for Sustainable Cotton Production was announced in December 1992 under the directorship of Principal Research Scientist with CSIRO Plant Industry Dr Greg Constable and Chairman Richard Browne. Along with CRDC, core partners were the then NSW Agriculture, QLD DPI, CSIRO Divisions of Plant Industry and Entomology, the University of New England and University of Sydney.

This laid the foundation for two successive CRCs, spanning 18 years with the Australian Cotton CRC (1999-2004) and Cotton Catchment Communities CRC from 2005-2012, generating more than $1 billion dollars in economic, environmental and social benefits for Australia (according to then NSW Department of Trade and Investment studies).

Under the Cotton Catchments Communities CRC, CRDC contributed more than 50 percent funding toward 'The Farm' program, which alone had an estimated return of $7 per $1 invested, to name just one example.

"Collaboration enables 'bigger picture' questions to be tackled among disciplines and with industry partners. There are opportunities to commercialise R&D, with the benefit of the CRC's access to specialised skills and resources across state and industry boundaries," says former Australian Cotton CRC Director Guy Roth.

"An independent review of the Australian Cotton CRC in 2004 said the CRCs had been successful in providing the industry 'immediate, feasible solutions to their on-farm production problems as well as long-term solutions addressing sustainability of their environment for future generations and the success of the CRC is reflected in the exceptionally high levels of adoption of its innovative research developments'.

"The industry demonstrated that it was not only totally supportive, but provided leadership and interacted strongly with the research activities and technology transfer approaches used to deliver solutions to the major problems associated with cotton production in Australia.

"Importantly, the dividends from this research and development journey will continue for many years to come for the industry and for the catchments and communities in which it operates."

CRDC continues with the same mantra today – working with a number of R&D Corporations and research providers on collaborative projects and seeking to further industry profitability through the Rural R&D For Profit program.

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Collaboration between research providers was identified by CRDC as the most useful way to capitalise on research capacity and investment. The notion of the first Cotton Co-operative Research Centre – for Sustainable Cotton Production – was developed by CRDC's early management led by Ralph Shulze. CRDC supported it and the successive two CRCs, which came to an end in 2012.

Being the best managers

There are many benefits to the Australian cotton industry's commitment to sustainability through best practice.

Best Management Practice (BMP) was developed in the mid-90s and solidifies the industry's commitment to sustainability and maximising management. Today it is used to give Australian growers a competitive advantage.

Australian growers are the most efficient in the world, have safer farm workplaces, healthier natural environments, better use natural resources and have significantly reduced some farm inputs.

As a result Australian cotton farmers are internationally recognised as leaders in sustainable cotton production and domestically are used as a model for change by other agricultural industries.

The cotton industry's flagship environmental program, BMP (Best Management Practice), has driven much of this achievement and has significantly changed the way cotton is grown in Australia. The evolution of the BMP program and production of "BMP cotton" has also led to better marketing opportunities through initiatives such as CottonLEADS and the Better Cotton Initiative which return premiums to growers and provide quality assurance to our customers.

BMP has its origins in a 1993 joint research program - *Minimising the Impact of Pesticides in the Riverine Environment* - undertaken by the newly-established CRDC, the then Land and Water Resources Research and Development Corporation and the Murray Darling Basin Commission, which sought to minimise the impact of pesticides on riverine and aquatic ecosystems in cotton-producing areas.

As a result of the research a 'Best Management Practices' approach to address pesticide management was agreed upon. Current CRDC R&D Manager Allan Williams led the development of the BMP manual, first released in 1997.

"Outcomes of the research informed the industry and CRDC as to what management actions needed to be taken – the BMP manual was then created to translate this information to growers and industry," Allan said.

"While focused on protecting and improving river health, it was also concerned to ensure that any response was founded in science and a good understanding of pesticide movement so that well-targeted recommendations on how minimising their impact could be developed."

The BMP manual was developed with a farmer-focused implementation strategy delivered by Cotton Australia. This led to an improvement in the way pesticides were used.

"From being seen as a poor environmental performer in the 1980s and 1990s, the Australian cotton industry is now a world leader in the implementation of more sustainable farming practice," Allan said.

"This is evidenced by the Better Cotton Initiative accepting BMP as meeting their requirements for growing 'Better Cotton' and the continual meeting of environmental targets set out in independent industry environmental reviews undertaken by CRDC in 2003 and 2012. Since these early days, the BMP program has been expanded to include water management, workplace health and safety, petrochemical storage and handling, energy use, fibre quality management and more.

Between 2008 and 2010 CRDC supported the conversion of the paper-based system to the web-based '*my*BMP'. This was to enhance delivery and usability in time with the evolution to growers' connectivity.

"The philosophy behind the BMP program was that the adoption of a best management practice system which is scientifically sound, credible and continually improving could demonstrate the industry's commitment to minimising its environmental impacts.

"No other countries have such a comprehensive system to assure we produce the world's most sustainable and quality product," Allan said.

"Over CRDC's lifespan, nearly all investment research has informed best practice, from the field to the warehouse."

Tracking sustainability

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Internationally, nationally and locally: consumers, governments and communities are increasingly interested in the sustainability of agriculture and its products.

Assessing, reporting, and improving on environmental performance provides assurance that the Australian cotton industry takes sustainability seriously and is continuous in its improvement.

The Australian cotton industry has a strong history of taking ownership of areas where it is having environmental impacts and minimising them through improved management based on sound R&D. Despite past achievements, the long term success of the industry continues to depend on how its practices, products and reputation are perceived by customers and the wider community.

The release of the *Australian Grown Cotton Sustainability Report* in 2014 marked 23 years of independent environmental reviewing, performance monitoring and practice change that is unparalleled among agricultural industries. The report was developed through collaboration between CRDC and Cotton Australia in response to the Third Environmental Assessment. The assessment identified 10 years of R&D-driven environmental achievements, including chemical use reductions, water use efficiency improvements, active engagement in landscape and catchment-wide natural resource management and the significant uptake of integrated pest and weed management.

A history of stewardship

In 1989, some 230,000 hectares of cotton were planted in Australia and production exceeded one million bales. The industry was becoming aware it needed to improve its environmental performance. Criticism of industry practices had come from the public, media and environmentalists for perceived poor environmental performance over pesticides, water use and soil degradation.

In 1991 the Australian cotton industry became the first major Australian agricultural industry to seek a comprehensive external assessment of its environmental performance and marked an industry-wide commitment to continuous improvement in environmental management on cotton farms.

Initial audit recommendations

This initial audit provided an overview of the entire value chain, identified key issues and concerns associated with its practices and assessed overall performance. The audit made 69 recommendations to which the industry responded with research, development and extension.

By the time of the second independent environmental audit, commissioned by CRDC in 2003, all 69 recommendations had been met. A major joint research and development initiative to come out of the audit was the Pesticides in the Riverine Environment project co-funded by CRDC, the then Land and Water Rural Research and Development Corporation, and Murray Darling Basin Commission between 1993 and 1998. This research spawned the industry's Best Management Practice Program (BMP) in 1997, also an initiative of CRDC.

The second environmental audit found that BMP was a major driver for improved environmental management on farms. Key recommendations for improvement covered familiar issues - water use and management, agricultural chemical, waste and vegetation management.

In 2005 Taking Responsibility for our Future – *The cotton industry action response to the Second Australian Cotton Industry Environmental Audit 2003* was released detailing industry's response to the 2003 recommendations and gave a public commitment to the next stage in the process of continuous improvement in environmental management within our industry.

The work continues

CRDC initiated the *Cotton Industry Third Environmental Assessment* in 2012, which identified achievements since the 2003 audit and future environmental priorities, making specific recommendations for the industry to continue to reduce its environmental footprint.

The industry responded to this assessment through the *Australian Grown Cotton Sustainability Report*, which in a first for the industry tracked the environmental, social and economic impact of Australian cotton against a set of sustainability indicators. Released in 2014, the report was prepared according to the principles and framework of the Global Reporting Initiative for Sustainability Reporting, reporting data on 45 economic, environmental and social attributes.

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Landing in the right place

Research into best practice spraying of all agricultural chemicals is vital to the cotton industry.

Best practice spraying methods protect the natural environment, improve efficacy, reduce inputs, manage resistance and deliver on industry's commitment to sustainability.

A project started by the Cotton Research Council in 1989 which received ongoing support from CRDC and the then QLD DPI, assessed the suitability of buffer zones containing foliage; the suitability of certain plants for use to capture pesticide droplets; and the behaviour of 'droplet clouds' moving across crops.

In 1990, aerial spraying was the preferred method of insecticide application – but came with limitations due to a lack of knowledge about the nature of drift and the science governing it. Reducing the movement and impact of agricultural chemicals became a core objective of the newly formed CRDC.

Along with significant investment in the collaborative *Minimising the Impact of Pesticides in the Riverine Environment* project (of which best practice spray application was a major component) other early research included development of a prototype ground sprayer to reduce drift near built-up areas, improvements to ground spray rigs, a wind tunnel to study air movement and extension of integrated pest management (IPM). Innovations from farmers and researchers were evaluated and adapted to improve the safety, efficiency and capability of spraying equipment.

During the 1990s CRDC supported the publication of the *Best Management Practices*, *SPRAYpak, Trees on Cotton Farms* and commissioned the *Review of Spray Application Research and Extension for Australian Cotton Farming Systems* to improve spraying practices manuel. CRDC supported the establishment of a ground rig operators group in 1999-2000. Along with pesticides, herbicides also have the potential to impact the broader environment. Not only does herbicide drift have the potential to affect the environment, cotton and other crops, it doesn't make economic sense for growers.

Today, thanks to a range of CRDC-supported projects relating to best practice spray application we know a lot more about the best use of spray equipment, how droplets move and the most suitable set up for particular situations. Most importantly this information has been successfully conveyed to end users. CRDC's long-term project on best practice spray application has delivered 24 application and drift management workshops to more than 500 cotton growers, advisors and applicators.

"Thanks to long-term research undertaken with spraying specialists, we understand more about the physics behind air movement such as pooling and inversions," said CRDC's Ian Taylor.

"The research into appropriate use of nozzles, weather and technology required a change in thinking, as we began to understand the science and the interaction with our natural environments.

"Through significant investment we have been able to produce some very specific guidelines to ensure best practice in spray application.

"Of particular importance to us is that the uptake of this knowledge has been fantastic among growers, and this has come about through the work of key specialists such as Bill Gordon who has run very successful spray workshops."

Technological advancements in computing also allowed the development of CottonMap with partners GRDC, Nufarm and Cotton Australia to highlight the presence all cotton fields in Australia, primarily to mitigate phenoxy damage to cotton crops.

"Along with a concerted drift management campaign from industry partners including agri-business, phenoxy herbicide damage has been lessened, however the issue remains a key focus for RD&E.

"CRDC research also investigated the effects of herbicides on cotton in terms of yield and maturity to aid growers in making better decisions about recovery management.

"Along with Cotton Australia we have also worked closely with Australian Pesticides and Veterinary Medicines Authority (APVMA) regarding label recommendations and best practice spray application," Ian said.

"Our most recent work has re-investigated buffer zones, what plants to use and how they should be configured for maximum effect."

The science of farming

Lint yield from Australian cotton crops has almost doubled since the adoption of locally bred varieties during the early 1980s.

Australian cotton growers are the best crop managers in the world, producing high yields and excellent fibre quality in often challenging environments.

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Long term records show that whole of industry yield during the 1960s had more than doubled in the 2000s to 1890kg lint per hectare (8.39 bales/ha per acre). There are now many examples of yields in excess of 3400kg lint per hectare (15 bales/ha).

While there is no doubting the part plant breeding has played in this, the role of Australian cotton growers world-class crop management and willingness to adopt best practice based on research cannot be understated.

Recent analysis by the CSIRO Plant Breeding team shows that variety contributes about 48 percent of the yield gain (160kg per hectare per year); management 28 per cent (95kg per hectare per year); and the interaction between variety and management contributes 24 per cent (80kg per hectare per year).

Farming systems research has been a particular focus for CRDC over the past 10 years as an area of significant investment.

During the time of the 2003-2008 Strategic Plan, CRDC invested $9.9 million in farming systems research (not including crop protection and integrated natural resource management program investments) in a time of severe drought. However cotton yields over the five seasons showed a 17 percent yield improvement. A survey of cotton crop consultants indicated that the major drivers of improved yields over those years were improved water and nitrogen use efficiency; cotton varieties; management of other plant nutrients; and crop rotations.

During 2008-13 CRDC invested a further $31.92 million in 205 research projects (from a total research output of $49.8 million) and the 2013-2018 Strategic Plan has allocated 35 percent of an estimated $100 million toward the 'Farmers' program under which farming systems research sits.

Farming systems research covers agronomic factors and decisions in crop production, including research into configuration, nutrient management, rotations, crop protection, water use efficiency, weeds, climate/weather and tillage. It is aimed at improving gross margins for Australian cotton growers and developing on-farm innovations and partnerships to drive profitability.

"The advent of Bt technology and uptake of integrated pest management, has allowed both CRDC and farm managers to shift more of their attention to crop management, and we have had to make sure agronomic information based on science is available to them," CRDC's Ian Taylor says.

"In the past 10 years alone CRDC has invested more than $20 million in farming systems research, which has delivered improved irrigation, nutrition and tillage information.

Lint yields of up to 3500kg per hectare are now being reported in some fully irrigated Australian crops. Researchers use this value to calculate 'yield potential' which is increasing through time as crop management and genetics improve. Theoretical yield meanwhile, helps us understand what could be achieved if we are able to manage stress with improved varietal adaptation or management. Former head of CSIRO Plant Breeding Dr Greg Constable and CSIRO Agricultures Dr Mike Bange recently reassessed this figure. They calculated theoretical yield for irrigated cotton to be 5000kg of lint or 22 bales per hectare in a long-season growing environment.

Comparing yields to the 'yield potential' can help to identify the 'yield gap' and can assist in identifying the production constraints in any cropping system, which will remain a focus for CRDC as it considers investment in farming systems into the future.

CSIRO plant breeder Warwick Stiller said the last season set a new benchmark of what can be achieved and with varieties like Sicot 74BRF there is still the potential for higher average yields.

"It's really pleasing to see the potential growers are extracting from our Australian-bred varieties and adapting management to achieve impressive yields in contrasting climates from Emerald in the north to Hay in the south," Warwick said.

World-leading Bt stewardship

Australia is now recognised as having the most pre-emptive, rigorous and successful resistance management system for transgenic cotton in the world.

A review in the journal *Nature* in 2013 analysed results of 77 studies from five continents reporting field monitoring data for resistance to Bt crops of the genes Cry1Ac and Cry2Ab. It found that after more than a decade of exposure to Bt cotton, the frequency of individuals with alleles conferring resistance to Cry1Ac and Cry2Ab in Australia remained at less than one percent for *H. armigera* and *H. punctigera*, as opposed to an increase to between one and five percent for *H. armigera* in China for Cry1Ac.

The report said (in comparison to China and the US) Australia has applied the most stringent refuge requirements, which may have substantially delayed resistance, starting with Ingard in the mid-1990s which required a minimum of 70 percent non-Bt cotton on each farm versus four percent in the US. For Bollgard II, Australia requires 10 percent non-Bt cotton or equivalent per farm, whereas the US eliminated refuge requirements in many regions.

In some countries the key targets of Bt crops overcame the technology in situations where no resistance management plan (RMP) was in place. No field failures have been recorded in Bollgard II in Australia.

The RMP for this technology is reviewed annually based on monitoring undertaken by CSIRO, supported by CRDC and CSIRO, into resistance in Helicoverpa to Bollgard II. CSIRO's Dr Sharon Downes

"Australia has applied the most stringent refuge requirements, which may have substantially delayed resistance."

9 leads the Bt Resistance Monitoring Program.

"Our testing provides independent advice to industry on how well the resistance management strategy is performing – a confidence in the RMP, and reassurance that the industry is taking a pre-emptive rather than reactive approach to resistance management," Sharon said.

"This is important because the strategies in place to prolong efficacy of the technologies can be practically arduous to a grower, yet Australia is arguably one of the most vulnerable countries in terms of resistance risk due to the profile of our pests – they are not particularly susceptible to Bt and have a history of developing rapid resistance to insecticides."

Prior to the release of the first Bt cotton Ingard in 1996, the industry acknowledged that the potential for *H. armigera* to develop Bt resistance was very real and that it was vital to be proactive. CRDC-supported projects aimed to establish how to monitor for Bt resistance and understand its characteristics and what that meant for its potential evolution. The work also focused on a better understanding of the ecology of *H. armigera* populations in an Australian landscape, particularly the aspects that can affect selection.

During 1997-98, varied results from Ingard's second season led to further projects around the deployment of Bt cotton and a reappraisal of sampling relationships and feeding behaviour of Helicoverpa on Bt cotton. Area-wide management strategies for *H. armigera* were launched in collaboration with GRDC, which proved successful.

A CRDC project with the then QLD DPI at Emerald investigated the value of chickpea and pigeon pea as trap crops grown on every cotton farm as an area-wide strategy to reduce *H. armigera* populations. This proved successful and refuges became an integral part of the RMP.

Around this time CRDC also supported investigations into other transgenes or mechanisms to enhance the efficacy of the products of transgenes and monitoring field populations for resistance – the start of the Resistance Monitoring Program, which CRDC still supports today.

The success of the industry's RMP paved the way for the approval and release of Bollgard II in 2004-05, which contained two genes. Prior to its release, the industry worked with regulators to ensure a pre-emptive resistance management strategy was in place.

Major cotton producing countries such as Brazil and the US are now learning from Australian researchers and R&D to manage recent incursions of *H. armigera*.

As the industry looks to the introduction of Bollgard 3, the Transgenic and Insect Management Strategy (TIMS) Bt Technical Panel has reviewed relevant research to formulate an RMP for the technology. This strategy will be supported by research into how to manage this third generation Bt cotton to maintain Australia's exemplary reputation for stewardship of the technology.

A future of capable people

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The Australian cotton industry may employ up to 14,000 people depending on seasonal and market conditions.

When it comes to an industry's sustainability and success, outstanding people make the difference.

A significant problem facing the Australian agricultural sector, including the cotton industry, is a lack of suitably qualified, skilled employees.

"One of the reasons for this situation is that the agriculture sector has experienced the largest decline in skilled labour of any industry in Australia – in the past 10 years, it has decreased by 27.7 per cent," says CottonInfo Education Officer Trudy Staines, whose role is funded through CRDC.

"There is an understanding within the cotton industry that success requires the right people with the right skills. Therefore it is essential we attract and retain qualified, skilled people with passion."

CRDC is working with industry to address workforce needs and improve human capacity. For CRDC, this involves a two-pronged approach - to support initiatives to upskill current people, and research and investment to find better ways to attract and retain talented people.

According to the University of Sydney, in 2010 there were just 743 graduates in agricultural science but over 4500 advertised agricultural science jobs.

"Since this time, however, there has been in increase in enrolments in agricultural-related studies at our universities: from a 15 to 20 percent increase in 2013 to a 30 to 35 per cent increase in 2015," Trudy says.

"It is likely that programs such as the Primary Industry Centre for Science Education (PICSE) – which exposes students and teachers to career opportunities in agriculture and science (supported by CRDC and cotton industry bodies) has contributed to the increase in enrolments in agriculture, along with industry-specific education programs, like those run by the cotton industry.

"Collectively, CRDC, CottonInfo, CSIRO, PICSE and Cotton Australia are working to engage students at all levels – from primary school to PhD."

In response to direct requests and feedback through grower panels which identified building industry people/ workforce capacity as a priority, 'People' became a stand-alone investment area in CRDC's 2008-12 Strategic Plan. This commitment has extended to the current 2013-18 Plan.

"CRDC also invested in many studies into labour markets and workforce research through partnerships with universities and consultants to better understand the state of the workforce, challenges and research priorities to meet future requirements," CRDC's Ian Taylor said.

"These confirmed we are facing a people shortage that is likely to persist at least into the near future. CRDC's investment and support for initiatives over a number of years is something we are very proud of, however we still have challenges to overcome in attracting and retaining people on farms.

"We do feel however that by proactively investing in programs to address these issues we are starting to have an impact in attracting people to the industry in key sectors."

Between 2012 and 2015, almost 3500 students were engaged in a cotton industry education activity through such initiatives as the Young Cotton Professionals program and PISCE which includes the Science and Engineering Investigation Awards, industry camps, placements and undergraduate internships, which are all supported by CRDC. An undergraduate internship program run by PICSE has seen 21 students engaged in cotton industry placements since December 2014.

"In an example of industry programs working in unison, interns from the PICSE program have graduated into the Young Cotton Professionals Program, which places university students into internships within the agribusiness sector of the cotton industry," Trudy said.

"As these students embark on their careers in cotton, future development and leadership opportunities await – from the Future Cotton Leaders Program to the Australian Rural Leadership Foundation's program, supported by CRDC, Cotton Australia and Auscott Limited."

Further programs building capacity supported by CRDC and partners include: UNE Cotton Production Course, Training Rural Australians in Leadership (TRAIL), Nuffield Scholarship, Peter Cullen Trust, Horizon Scholarship, international research leadership, Summer and Honours Scholarships, Field to Fabric, Cotton Ginning course and PhD Postgraduate Tours. This is in addition to the many initiative CRDC has supported aimed directly at growers, managers and consultants.

The first post-doctoral fellowship awarded by CRDC was to Dr Stuart Gordon - and the doctor is 'still in the house' today as the inventor of the world's quickest and most direct technology to measure fibre maturity and as the Principal Research Scientist at CSIRO Manufacturing where he leads the post-harvest cotton research effort.

Valuing researchers and fibre quality

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Stuart's continued contribution to the Australian cotton industry through his research, innovation and leadership stands as a testament to the value of identifying talented researchers early and supporting them through their journey to become world-leading scientists and industry leaders.

It was Stuart's post-doctoral research which spawned the idea for his ground-breaking invention Siromat, a simple but novel instrument to measure fibre maturity. Siromat has since been coupled with Dr Geoff Naylor's Cottonscan to develop the Cottonscope instrument – the first instrument to measure both fineness and maturity directly and accurately. CRDC has been a supporter of both these innovations.

"While my PhD was to examine cotton's physical and chemical properties, it ended up looking at measuring fibre maturity and properly distinguishing low-micronaire cotton, which at the time, was being discounted, for fear that it immature," Stuart says.

"This situation still occurs albeit now there is an accurate instrument that can separate coarser, immature fibre from fine, mature premium fibre."

Stuart started his PhD in 1990 with CRDC's predecessor the Cotton Research Council after responding to an advertisement for a post-graduate studentship.

"The then Managing Director Ralph Schulze, along with my supervisor were looking at the cotton post-harvest area in terms of promoting and managing Australian cotton fibre quality and developing future expertise in this area," he says.

"I finished my PhD at the end of 1993 and was awarded the CRDC post-doctoral fellowship, which I spent in New Orleans with the US Department of Agriculture and with the Australian cotton spinning industry."

Dr Stuart Gordon was CRDC's first post-doctoral fellow, awarded in 1993 and is also the inventor of the world's quickest and most direct technology to measure fibre maturity. He is pictured with Hy Hwang, a collaborator in the commercialisation of the instrument at the Australian Cotton Conference in 2008.

At the end of this invaluable fellowship Stuart began working with Rocklea Spinning Mills, then Australia's largest cotton spinning company. At the time they operated three spinning mills and a dye-house and produced in excess of 20,000 tonnes of yarn per year. At Rocklea he became overtly aware of the importance of fibre quality and its impact on yarn quality and the spinner's bottom line.

"Rocklea used 100 percent Australian cotton and half of its yarn was exported, however the cotton at that time was not really good enough to spin fine count ring spun yarns - it wasn't long or strong enough," Stuart said.

"It was good for open end yarn to Ne 30 (20 tex) and the same counts in ring spun yarn but not for finer ring spun yarn.

"Rocklea operated Australia's only ring spinning mill at the time and we could not consistently spin Ne 40 (15 tex) yarn to be used in fine knits and fine-medium weight wovens. This was the same for overseas mills using Australian cotton.

"It was the mills (largely from Japan at

the time and Australia) who exerted pressure on the Australian cotton industry via the merchants to improve its fibre quality."

The CSIRO cotton breeding team had already responded to this challenge first under Norm Thompson in the 1980s and then Greg Constable and his team into the 1990s.

Stuart joined the CSIRO Division of Textile and Fibre Technology in late 1999, which had just changed its name from CSIRO Wool Technology which was looking to diversify its research capability away from wool and Stuart's work began into creating Siromat.

"Geoff Naylor had already started a year before with a small grant from the CRDC to develop instrumentation for measuring cotton fibre fineness," Stuart said.

"Luckily for me and the industry, Ralph and others were keen to have cotton valued properly for fineness and maturity, and also to grow Australia's expertise and R&D profile in the post-harvest area."

Stuart and Geoff's work resulted in two patents - one for fineness and one for maturity. These were licensed to BSC Electronics in 2010 which incorporated the two technologies to form Cottonscope, which is now commercially available and used by cotton breeding programs in Australia and the US and spinners elsewhere. It is estimated that more than 20 percent of the world's new cultivars are selected on the basis of Cottonscope values for fineness and maturity.

Stuart's contribution did not end there. As the resident CSIRO post-harvest cotton expert he was also responsible for building CSIRO's cotton infrastructure (laboratories, a gin and Australia's last surviving ring spinning mill) and capability; recruiting scientists to support industry in this area.

"We recruited René van der Sluijs in 2003 and Rob Long as a post-doctoral fellow in 2006, as well as recruiting from the incumbent expertise at CSIRO (in wool and textiles) for cotton," Stuart said.

"Our survey work of spinning mills using Australian cotton started in 2002 with support from the Australian Cotton CRC, followed by ginning work with support from CRDC and the Australian Cotton Ginners Association."

With further support from CRDC and the International Fibre Centre, the Field to Fabric Course began in 2003 and the ginning and post-harvest BMP audits in 2005-06. Research into managing crop physiology for fibre quality was instigated in 2006 with support from the Australian Cotton CRC. Our work has also seen the development of CSIRO's gin sensor (for moisture and contaminants) and yarn quality prediction program (Cottonspec).

Today, Australian cotton is highly sought after by spinning mills around the world thanks to achievements under guidance of people like Stuart. Australian bred and grown varieties lead the world in strength, maturity and fineness. BMP audits of Australian gins and classing houses are routine and our gins employ methods to reduce fibre breakage and contamination during ginning.

Cottonspec, the fibre quality prediction tool is on the verge of commercial uptake and the managing crop physiology for fibre quality work has given rise to new approaches for improving fibre quality at the grower end.

The Textile and Fibre Technology Division merged with CSIRO Materials Science and Engineering in 2007 (now CSIRO Manufacturing), and relocated to Deakin University's Waurn Ponds campus in 2013. Here collaborative work with Deakin University's Institute for Frontier Materials on CRDC and Cotton Inc. projects in the areas of product development, instrumentation, fibre processing, cotton cellulose's structure and new materials from cotton continue.

Ginning research has improved the quality of Australian cotton fibre.

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Efficiency on the rise

Australia's cotton growers lead the world in water use efficiency, producing more lint per megalitre than any other nation, at around two bales per megalitre of irrigation water.

In terms of yield per hectare Australian growers produce more than two and a half times the world average.

Against the background of the worst drought on record and a national agenda for water reform, in the early 2000s the Australian cotton industry set itself a challenge to double its water use efficiency (WUE). By 2009-10 Australian growers almost doubled their Irrigation Water Use Index from 1.1 in 2000-01 to 1.9 bales per megalitre (ML) in 2009-10. Australian cotton growers now produce more cotton with less water per hectare than ever before.

CRDC's strategic investment with research partners on behalf of cotton growers and the Australian Government has played a major part in this achievement. It's the result of an enormous research and extension effort with adoption and innovation by growers.

Growers are now using a range of techniques to constantly improve WUE including in-field moisture monitoring, improvement to field and irrigation system design, reducing evaporation, scheduling technology, improved soil health and new irrigation techniques.

According to the CRDC-commissioned *Third Australian Cotton Industry Environmental Assessment* (2012), Australia's cotton growers have improved their water use efficiency by three to four percent per annum since 2003.

The Australian cotton industry has used values of Gross Production Water Use Index ($GPWUI_{farm}$) to benchmark WUE since 1988-89. Research comparing $GPWUI_{farm}$ found that growers are as efficient in full production as in low planting years. In the record 2012-13 season $GPWUI_{farm}$ was 1.12 bales/ML, compared to 1.17 and 1.14 bales/ML in 2006-07 and 2008-09 respectively.

Over the years, CRDC invested in research to first quantify water use and losses, and subsequently, investigated how to improve on this. As a result growers have embraced research outcomes to more closely monitor water use, adopt new technology and undertake capital works such as improving and redesigning water storages and channels to reduce leakage and evaporation, with more efficient delivery of water to the field.

While RD&E investment has been successful in assisting growers to optimise drip and sprinkler irrigation systems, furrow irrigation is most commonly used. Studies show that 96 percent of irrigators have made changes to their furrow irrigation systems to improve efficiency. Application efficiency and uniform application have been maximised, as have monitoring efficiencies and calculating water use. The portfolio of research has extended across crop, farm, catchment, community and industry scales.

Recently CRDC has invested in projects to use satellite telemetry, canopy temperature sensors and soil water monitoring technology to better schedule irrigations using real time adaptive control of irrigation application. Row configuration trials also allow growers to make the most of water availability particularly in seasons of low allocation.

Water R&D knowledge has been compiled and extended through the CRDC-supported industry publication *WATERpak*. This resource has been revised and extended to include grain production to integrate with the *my*BMP program.

CRDC studies such as the Third Environmental Assessment, grower surveys and the study by industry researchers and specialists show there is still noticeable variation in WUE on a farm-by-farm basis. Going forward, CRDC is focused on ensuring through RD&E that all growers are aware of the technology and know-how to maximise their water use efficiency.

CRDC supported research has highlighted the critical importance and role soil carbon has in promoting soil health, improved productivity and sustainability.

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The value of carbon

CottonInfo Carbon Technical Specialist Jon Welsh and UNE Research Fellow Rhiannon Smith taking samples of river red gums in the Namoi Valley. Both Jon and Rhiannon have been working to quantify the part native vegetation and riparian zones play in carbon sequestration on Australian cotton farms.

Research has shown that practices for optimising energy and input efficiency and reducing emissions in cotton production are also those that deliver maximum yield and environmental benefits such as improved soil health.

CRDC has supported RD&E efforts into understanding and reducing nitrous oxide emissions on cotton farms, understanding of carbon in soils and management practices in reducing Greenhouse Gas (GHG) emissions. Research undertaken by NSW DPI's Dr Nilantha Hulugalle found greenhouse gas emissions can be reduced through modifying farming practise. Eliminating inversion tillage, minimising groundwater use, choice of rotational crops, optimising applied nitrogen fertiliser rates and substituting legumes all contribute towards reduced GHG emissions.

Research into carbon storage and carbon sequestration on floodplain soils, riparian zones and native vegetation (in particular river red gums) has shown that emissions from farming activities can be entirely offset by these non-cropped areas and carbon-neutral cotton farms are a possibility.

A recent Life Cycle Asessment to determine the carbon footprint of cotton production at "Wyadrigah" near Mungindi in Northern NSW found the farm to be carbon-neutral.

"We also found that healthy riparian zones are the greatest contributor to this," says CottonInfo Carbon Technical Specialist Jon Welsh.

"Riparian zones are the quiet achievers in the cotton system and research findings on carbon sequestration rates of river red gums only adds more value to these areas.

"We also know through previous CRDC investments, such as the Cotton T-shirt Lifecycle Assessment, that the largest source of greenhouse gases in a cotton system is nitrous oxide from synthetic nitrogen use and chemical processes in the soil from denitrificiation followed by direct energy use from irrigation practices."

CRDC commissioned a Life Cycle Assessment study to evaluate the environmental impact of a 100 percent cotton t-shirt throughout its life cycle and examine how the industry could further reduce its carbon footprint. This groundbreaking research demonstrated that the major environmental impact was in the 'use' component, rather than in the growing or manufacture of the garment.

It showed that during the growing phase, the biggest contributor to cotton's carbon footprint was related to synthetic use of nitrogen fertiliser use and losses. This was confirmed through another CRDC study in 2014.

CRDC has been investigating nitrous oxide emissions from cotton fields since 2002, and more recently, supported a study into losses of nitrous oxide from the irrigation system to identify how this can be improved. The effect of management practices on soil carbon, temperature and rainfall has also demonstrated that rotations such as corn may have multiple benefits including sequestering higher soil carbon, greater water holding capacity and higher cotton yields.

These activities have been the subject of continued cotton RD&E efforts, and are captured in the industry's Best Management Practices program, which include components on Energy and Input Efficiency, Water Management and Soil Health.

Since this study CRDC has directed significant investment to better understand the uptake and use of nitrogen by the cotton plant, optimal rates, timing, product and application and how management can be improved to improve efficiency and reduce emissions. This has seen the development of a whole farm web-based carbon footprint calculator, which is due for release in 2016. Accompanying products developed with assistance from CRDC such as EnergyCALC and EnergyCalc Lite are also aimed at helping growers evaluate and reduce energy and inputs which can lead to a reduction in the carbon footprint.

"Research into floodplain soils, riparian zones and native vegetation has shown that emissions from farming activities can be offset by these areas and carbon-neutral cotton farms are a possibility."

Advancing soft control options

A major objective of CRDC since its formation has been research into alternative methods of insect control to reduce the reliance on conventional pesticides to improve crop and environment protection.

Dr Robert Mensah, entomologist Dr Lewis Wilson (CSIRO) and progressive cotton grower Peter Glennie from Moree. All three have had a long and active association with the cotton industry. Peter has been a forward thinker in insecticide resistance management who has worked with Robert over many years through trials on his farm. Lewis has been involved in the cotton industry for around 30 years and been a leading light in developing integrated pest management.

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CRDC's Ian Taylor says integrated pest management (IPM) is critical for sustainable pest management in cotton and although challenged with resistance to conventional insecticides, the industry was always looking for ways to conserve beneficial insects and become more targeted in managing particular pest species as part of an overall integrated pest management (IPM) approach.

CRDC has invested in a number of long-term studies to develop biologically-based products for insect control - most notable being Sero X, which is in the advanced stages of registration and may be registered for use against Helicoverpa and sucking pests in this 2015-16 cotton season.

After a 10-year study led by Dr Robert Mensah, a Senior Principal Research Scientist with NSW DPI, Sero X was developed for the control of *Helicoverpa* spp. and sucking pests (mirids, aphids, whitefly and small nymphs of green vegetable bugs) in conventional and Bt cotton crops.

Sero X was developed from secondary plant compounds (SPCs) from an extract of a plant species (*Clitoria ternatea*) prevalent in Australia that can deter pest feeding and egg laying as well as directly killing of a number of insect pests. These SPCs are biological compounds or semiochemicals used as biological pesticides and are preferred in IPM programs as they provide effective control of a pest with minimal impacts on beneficial species and the environment.

Robert says another significant benefit of the type of natural compounds in Sero X is the low risk of resistance developing because the pest control properties of the product are not due to one or two unique bioactive compounds, but many different chemical compounds providing a number of modes of action. Therefore it is unlikely that resistance will develop to these complex organic compounds.

Robert is also developing an Entomopathogenic fungus for the control of *Helicoverpa* spp. and sucking pests on cotton with funding from CRDC. The research has been ongoing since 2005 and is in the advanced phase of negotiation and commercialisation.

Magnet, developed by Professor Peter Gregg and Dr Alice Del Socorro from the University of New England through the Cotton CRC was registered for use in 2009 following 10 years of research. Magnet was designed for use in conventional cotton and CRDC has recently supported a project studying the 'lure and kill' potential of the product for use in Bt cotton.

Most recently, CRDC has invested in blue sky research into biopesticides with NSW DPI and Western Sydney University to develop novel IPM products for the industry.

"Working through the process of commercialisation of these types of products provides great benefits for the industry and also to the scientists involved," Ian says.

"In addition there is now a greater appetite with some of the more established pest management companies to explore biological pesticides.

"Without its early investments, CRDC and the industry's researchers would not be in a position to work with some of these companies to introduce biologicals into the cotton farming system.

"There is no silver bullet when working to manage highly adaptive and successful insect pests, however with carefully planned strategies and a multi pronged approach that incorporates the judicious use of GM technologies such as Bt cotton, targeted and specific conventional insecticide chemistries, and the use of soft options including bio-pesticides, the cotton industry is developing a platform that will enable us to grow cotton sustainably into the future while minimising our environmental footprint."

Creating demand

Reducing post-harvest costs and better meeting market requirements was one of the first objectives of CRDC.

To reach this goal required research as well as improved consultation with the post-farm gate sector and customers such as spinning mills.

In its first years, CRDC held a 'marketing seminar' and a value adding conference, bringing together researchers, marketers and processors to identify issues warranting research. A joint-industry and CRDC program was initiated with spinning mills to assess fibre characteristics of importance to the textile industry, as part of a long-term plan to characterise fibre qualities of Australian varieties. The results confirmed the excellent fibre quality and spinning characteristics of our cotton. An independent review confirmed this, and the results were used by marketers to the benefit of growers.

CRDC increased research post-farm gate research capacity at ACRI with a 20-saw gin which was bought from the United States, installed and fitted in time for the 1991 harvest.

The goals to strengthen the industry's reputation for quality, promote industry values in production and provide value across key parts of the value chain continue to this day. The focus is on adding value to the industry with premium products and improved routes to market. This has required understanding current markets and potential opportunities, developing a market strategy and establishing environmental credentials.

CRDC convened the 'We're Aussie, Wear Aussie' forum in 2009 to chart a program of agreed future actions. The forum brought together high level supply chain representatives. The outcome was the industry's Premium Cotton Initiative supported by Cotton Australia, Cotton Seed Distributors and Australian Cotton Shippers Association. The initiative has a strong collaborative network in the industry and included trials of the premium varieties Sicala 340BRF and its predecessor Sicala 350B.

Australian cotton being spun in Dongying Hongyuan Textile Mill in China. (Courtesy John Hamparsum.)

Through international mills and brand owner surveys, promoting the uptake of BMP throughout the value chain, and premium yarn production, CRDC gained sophisticated market intelligence about opportunities for marketing of Australia's high quality cotton and responsible production practices.

Armed with this new understanding, CRDC worked with Cotton Australia, Australian Cotton Shippers Association and Cotton Incorporated (USA) to develop the CottonLEADS program in 2014. This program now complements Cotton Australia's broader 'Cotton to Market' program which incorporates both CottonLEADS and the Better Cotton Initiative.

Beyond market research CRDC has made major investments in researching the agronomic factors affecting fibre development, to minimise negative fibre traits such as neps and short fibre content, while improving fibre length, strength, fineness and maturity. The results have been extended through the *FIBREpak* publication which brought together critical findings from past and current research into fibre quality. Active promotion of this resource has led to practice change across the industry, including variety selection, irrigation and nutrition management, defoliation and picker/harvest preparation and management.

Further investment has seen the development of novel technology to improve spinning of Australian long staple cotton; the world-first Cottonscope software to assess fibre maturity and fineness; Cottonspec, which allows mills to predict final yarn quality; cotton-wool blend fabrics; contamination sensors and modified lint cleaners for gins; the gin moisture sensor Siroduct; and changes to quarantine treatments of cotton which were affecting quality.

Increased knowledge about maximising fibre quality in cotton production, ginning and spinning has resulted in improvements in fibre quality, reduced contamination and better market access for our cotton.

Way ahead in weeds management

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Glyphosate-tolerant and glyphosate-resistant weeds are now a reality in the cotton farming system and CRDC has been proactive in its approach to the issue.

Controlling nutgrass in the first cotton crops in the Namoi Valley was the first weeds research project CRDC supported.

In its first year of operation CRDC enlisted Graham Charles, NSW DPI, to undertake the project and from its inception, weeds' resistance to herbicides was on the agenda. Initial research centred around how to control weeds while avoiding development of resistance to herbicides.

"Right from the start growers were battling weeds and discussions around research priorities centred not only on controlling them but how to avoid going down the path of resistance," Graham said.

"Some growers were experiencing such heavy losses due to weed infestation they were forced to plough crops in.

"We acknowledged resistance would come, and quickly realised we needed a whole systems approach to weed management, which laid the foundation for what we now refer to as integrated weed management (IWM).

"Therefore research was focused on identifying weeds on cotton farms and developing the best control strategies that to fit the whole farming system.

"Today we are very good at managing weeds in cotton fields: it is the fallow areas where the bigger challenges lie."

CRDC supported the development of *WEEDpak*, released in 2002.

"It was the first of its kind accross any agricultural industry in Australia," Graham said.

"I remember Dave Anthony (then Auscott Namoi manager and CRDC board member) said to me, 'I want to know everything you know about weed control, what works and what doesn't work'.

"The Australian cotton industry was way ahead of the curve nationally and internationally with the release of *WEEDpak*, and has remained so to this day.

"You only have to look to the US cotton industry to see the impact resistance can have, or in Australia to rain grown cropping systems where most resistant weeds are found."

CRDC's support for weeds and herbicide resistance research and development culminated in the release last year of an industry-wide Herbicide Resistance Management Strategy (HRMS). Furthermore, the *2013 Report to Industry* says weeds R&D showed a return of $8.90 per dollar invested over the five years of the last strategic plan (2008-13).

Today CRDC supports researchers who have been responsible for cracking open the resistance enigma through understanding the genetics of glyphosate resistance, modelling, management, and annual weeds surveys.

Practices to either delay/avoid herbicide resistance or to control glyphosate-tolerant species bring with them the need to allocate additional resources for weed management. Farm managers are faced with difficult trade-offs between maintaining present profitability; and the cost-efficiency of increasingly difficult weed situations in the future.

"You can't spray your way out of herbicide resistance, as this inevitably selects for resistance; and since there have been no new modes of action since 1982 we would very quickly cycle through the existing modes of action for weed control," CRDC's Ian Taylor said.

"There are no silver bullets, but using what we've learned from the research we can select key tactics that will maximise the longevity of the farming system.

"It requires IWM - controlling survivors and managing the seed bank. Of course good farm hygiene underpins weed management.

"Through R&D our aim is to create new capacity for growers to improve input efficiency, maintain the current minimal yield losses due to unmanageable weeds, and shift towards practices that offer reliable weed management in the long term."

Optimal soil health

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Soil health and nutrition are key to achieving high cotton fibre quality and productivity.

Long-term soils research has laid the foundation for the industry to continue to build a bigger 'profile' of cotton growing soils and how best to manage them. Independent appraisal of CRDC soils and nutrition R&D found an estimated return of $26 to the industry per $1 invested over a 20-year period (1994-2014).

Soils are a complex of minerals, organic matter water and air. The earliest CRDC projects focussed on soil structure management and remediating soil compaction; improving soil biological health; amelioration of potassium deficiency; safeguarding against salinity; and studies into the value of permanent beds. With assistance from CRDC, crop rotation trials in several cotton regions were established to study crop nutrition, soil physics and chemistry, entomology, economics and biology.

Some of the earliest grower workshops convened by CRDC (1993) were around soil health, as well as industry meetings to aid co-ordination and planning of soils research. Field training programs associated with SOILpak, a soil management system funded by CRDC were held and a committee was formed to co-ordinate the updating of SOILpak, with many years of research now underpinning this resource.

One of the CRC for Sustainable Cotton Production's core programs was protecting the resource-base, particularly soil and water, and this continued throughout all CRCs to 2012.

Of great benefit to the industry has been the long-term rotation and nutrition trial project which began under CRDC in 1994 at the Australian Cotton Research Institute and continues to be supported by CRDC. Investigating rotation crop stubble management options on water conservation, nutrition needs and soil carbon levels are just a few areas of research undertaken through this investment.

Part of this research has now shifted from the impact of rotation crops on nitrogen fertiliser requirements to whether new higher yielding varieties have different nutrition requirements.

"This long term research has also shown that carbon neutral cotton farms are a possibility. A CRDC study into the effect of management practices on soil carbon, temperature and rainfall indicates that rotations such as corn may have multiple benefits including higher soil carbon and higher cotton yields, lower disease, such as black root rot incidence; and are more energy efficient in terms of energy produced relative to that used," says former NSW DPI researcher Dr Nilantha Hulugalle, who is now working with the Australian National University.

Nilantha has more than 20 years' experience in soil research and has focused on the impact that management has on soil quality issues such as sodicity and salinity, greenhouse gas emissions and soil water storage. The outcome of this research has seen the increased use of rotation crops in cotton farming systems, uptake of minimum and no-till cotton, and stubble retention from rotation crops that can improve soil water holding capacity.

"We now know that soil water storage can be increased by leaving standing stubble from rotation crops, with less frequent irrigation, while also conserving moisture from rainfall," he said.

Research undertaken by the late Dr Ian Rochester showed that very high yields (14 bales/ha) were achievable using leguminous rotation crops, which improved overall soil health and the soil's ability to sequester carbon. Ian also developed a method to easily identify nitrogen fertiliser use efficiency (NUE). This and associated research has developed optimal rates for nitrogen application and seen significantly increased fertiliser uptake efficiency from 30 percent to as high as 70 percent.

This research was also channelled into the development of NutriLOGIC, which allows growers to assess the nutrient status of the soil or crop and tailor management decisions.

Compaction was flagged as a looming issue in CRDC's early years and with the evolution of larger, heavier machinery CRDC has invested in several projects to better understand and mitigate compaction. It forms the ever-widening scope of research into soils which includes regional research in areas such as the Macquarie Valley, where little data is available on soils in the region.

"It is through a better understanding of our soils and adjusting our management to suit specific soil types that we can hope to best use this invaluable resource and maintain its sustainability into the future," CRDC's Ian Taylor concludes.

A comprehensive approach

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Managing the threat from disease has been a focus for CRDC, from its beginning.

The breeding of Verticillium-tolerant cotton one of the first CRDC projects in 1990, along with continuing support for Dr Stephen Allen's research at the then Narrabri Agricultural Research Station.

CRDC's current RD&E focus is on collaborative efforts to better understanding the ecology of these endemic and exotic threats by developing industry strategies and management tactics to address them. According to one of the world's leading disease experts, "Australian research presents a comprehensive and co-ordinated approach to the management of major cotton diseases in Australia".

Professor Craig Rothrock of the University of Arkansas visited Australia last year and said it was obvious from speaking with our growers that research is responsive to growers' concerns. Along with other leading US researchers Craig was attending the FUSCOM (Fusarium Wilt Research and Extension Coordinating Committee) annual event supported by CRDC. This vital gathering brings together Australia's pathology and virology research community, plant breeders, growers and consultants to share information and co-ordinate efforts on disease control. Originally formed to focus on fusarium wilt, today the FUSCOM research focus has broadened to other fungal and bacterial diseases.

It is this industry response to Fusarium that has shaped the collaborative approach to disease research that focuses on an integrated approach. In 1993 Fusarium wilt of cotton (caused by *Fusarium oxysporum f.sp. vasinfecta*) was identified for the first time in Australia, and the industry immediately embarked on an extensive RD&E program to manage the disease. While it was recognised that breeding would be the cornerstone to a solution, CRDC has supported all aspects of the Fusarium problem, including containment, farm hygiene practices, rotational crops, stubble management, weed management, ecology (including role of planting temperature), biocontrol, and molecular characterisation of the pathogen.

By 2000, Fusarium wilt had spread to all production areas except for Emerald in Queensland, Tandou and Hillston in NSW and Western Australia and it was estimated that Fusarium wilt caused $57 million in losses to the Australian cotton industry in that year.

Darling Downs' grower Graham Clapham has supported more than 20 years of Fusarium research, on his farm "Cowan". He recounts that in the late 1990s and early 2000s, Fusarium wilt was very serious for the Darling Downs, along with some other growing regions.

"The Darling Downs irrigated areas probably had the biggest risk," Graham says.

"In extreme cases, on our cotton enterprise, there were total losses - we would take fields out as they simply didn't have enough plants left.

"The majority of affected fields had a minimum of 30 to 40 percent yield loss."

Graham says that the research effort has been 'invaluable'.

"By understanding the conditions that promote Fusarium, we can adopt practices to minimise the risks.

"Accompanied by varieties that have been bred for tolerance, we are at the stage where we can sow cotton in previously affected fields with a high degree of confidence."

Annual disease surveys are a major element in CRDC's long-term disease management investment and play a major role in its success. Survey data from around 32 years in NSW and 13 years in Queensland indicate the relative importance of diseases and the impact management practices and the adoption of new varieties have on disease distribution, incidence and severity. Biosecurity of the Australian cotton industry has also been enhanced with the inclusion of surveillance for exotic diseases.

CRDC has and continues to invest in pathology research capacity for disease management such as black root rot, Fusarium and Verticillium wilts, seedling disease and reniform nematodes as well as maintaining biosecurity preparedness and pathology services for disease identification. Research extends from understanding the ecology of the pathogen such as weed and other crop hosts, spread and favoured environmental and microbial conditions, through to management tactics to reduce spread or severity.

Communication of these findings has also been supported by CRDC through the publication of *DISEASEpak, Cotton Pest Management Guide, Cotton Symptoms Guide,* and fact sheets as well as field days, conferences and forums.

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Protecting the crop from outside threats

Beyond competition from man-made fibres, CRDC's main investments in protecting the cotton industry is in its capacity to deal with biosecurity threats through surveillance and development of diagnostic protocols and contingency plans.

Long-term industry advocate and CRDC Board Director Greg Kauter was involved in drafting the biosecurity plan.

Throughout CRDC's history it has been responsible for raising awareness through biosecurity campaigns in integrated pest and weed management, as well as supporting related industry campaigns to promote Come Clean Go Clean and vigilance around identifying and recording possible harmful diseases, insects and weeds.

Australia's geographic isolation has meant that we have relatively few of the pests and diseases that affect agricultural industries overseas. From its beginnings CRDC has helped to ensure that the Australian cotton industry was aware of potential threats through the support of international travel and science exchanges. This meant the industry was on the front foot following the identification of silverleaf whitefly (*Bemsia tabaci* Type b) in 1994.

While most infestations were in the nursery industry, CRDC provided funds to survey cotton growing areas. No reports of damage to cotton were reported, but due to the pests' ability to develop resistance to insecticides, CRDC supported a preliminary investigation to determine the resistance status of these introduced strains found in Australia, believed to have entered through nursery stock.

Working with the Horticulture RDC, a co-ordinated R&D program was established to determine distribution, rate of spread, biology and ecology of silverleaf whitefly (SLW), establish a resistance profile, and study potential sources of viruses that could be released from other plants into cotton by this pest. When SLW flared in Emerald some years later, CRDC was able to transition the research focus to pest management.

This experience provided a reminder of the need for preparedness in the event of a pest or disease incursion.

Biosecurity planning provides a mechanism for the cotton industry, government and relevant stakeholders to actively determine pests of highest priority, analyse the risks they pose, put in place procedures to reduce the chance of pests becoming established, and minimise the impact if a pest incursion occurs. With the assistance of the Australian Cotton Growers' Research Association (now Cotton Australia), an Industry Biosecurity Group (IBG), co-ordinated by Plant Health Australia, was formed to work on the development of a cotton industry biosecurity plan in 2004. CRDC was actively involved in the development of the plan and also supported pathology and entomology researchers contributing to the knowledge and research capacity that underpinned its development.

CRDC has responded by expanding the scope of the annual disease surveys to include presence and absence of high priority diseases, supporting the development of diagnostic and contingency plans for many of the high priority pests and supporting industry training on biosecurity.

Insect vectored viruses, such as cotton leaf curl virus and blue disease, have been a particular focus of recent research given their ability to spread very quickly and cause significant crop losses. Investment in this area has resulted in increased understanding in the location of these virus, development of capacity to accurately detect virus, assessment of risks and development of contingency plans.

In recent years, CRDC projects have identified the presence of defoliating strains of Verticillium wilt in cotton production areas of Australia, the ASIA II silverleaf whitefly in the North Territory and the aphid vectored blue disease (cotton leaf roll virus) in East Timor. As a result of CRDC investment in assessing risks associated with cotton leaf curl virus, there have been changes to import conditions for high risk species, to ensure that potential symptomless hosts such as some hibiscus species are screened for the virus.

CRDC funded the 2015 review of the Industry Biosecurity Plan and continues to ensure the cotton industry has the capacity to minimise the risks associated with pests and to respond effectively to any pest threats is a vital step for the future sustainability and viability of the industry.

Safer cotton farms

Tony Lower of the Australian Centre for Agricultural Health and Safety says the Australian cotton industry is a leader in Workplace Health & Safety (WHS) investment and outcomes in agricultural terms, both nationally and internationally.

"The level of commitment shown by the cotton industry to farm safety is way ahead of other industries," Tony said.

"CRDC has been a long-term contributor to safety research and initiatives that help growers to implement approaches in a practical manner.

"This investment is having a significant impact on reducing injuries and increasing returns to growers.

"The lower workers compensation premiums paid by the cotton sector in comparison to other agricultural commodities and the steady decline in these rates, are strong indicators of how good health and safety performance can reduce costs and contribute to better profitability."

Workers Compensation rates for the cotton industry are considerably lower than that for other comparable sectors: 56 percent below that of beef cattle and 32 percent below sheep and mixed cropping-sheep-beef. These rates are based on performance – that is the more claims there are and the higher the costs the more the premium gets raised.

CRDC investigated farm worker health when it commissioned a study in its first year into the effect of pesticides on farm workers. Soon after, CRDC developed the *Managing Cotton Farm Safety* resource for cotton farms. This comprehensive resource was later used for the Managing Farm Safety on Cotton Farms course, supported by CRDC and run by Farmsafe Australia, with 500 cotton businesses participating. CRDC was also a partner in the Farm Health and Safety R&D Program managed by the Rural Industries Research and Development Corporation.

This *Managing Cotton Farm Safety* resource has been updated over time and is still used as a reference tool for the materials on *my*BMP, where most of the WHS resources now are found. Helping growers identify risks on cotton farms, practical resources and agricultural extension involving growers in striving to reach best practice, has all contributed to the industry's improved safety record.

Recent independent reports by the Australian Centre for Agricultural Health and Safety have shown that through implementing best management practices and the application of new technology such as Bt cotton, hazards on cotton farms have been drastically reduced.

The industry's focus on good health and safety has also been beneficial in becoming part of the Better Cotton Initiative, which takes into account work health and safety.

"The attention that is paid to health and safety through the *my*BMP platform, allows growers to more easily meet the health and safety requirements of the industry and the Better Cotton Initiative," Tony said.

"However while technological improvements and growing practices have assisted with enhancing health and safety, recent analysis funded by CRDC illustrates that injuries continue to cost the industry conservatively $3 to $4 million per annum."

As part of its ongoing to commitment to WHS, CRDC is seeking to address this through its recent involvement with the Primary Industry Health and Safety Partnership (PIHSP), which studied the barriers to adoption of farm safety. Through PIHSP the cotton industry will focus on delivering a clear message - that systematic hazard and risk management can improve safety and the profitability of farm businesses.

Next year will mark the 18th Australian Cotton Conference – the industry's premiere event showcasing the industry.

An industry showcase

From humble beginnings in 1982 with a small gathering at a hall in Goondiwindi in the Macintyre Valley of Southern Queensland, the 'Australian Cotton Growers Research Conference' has grown to be one of the biggest of its kind anywhere in the world, hosting 1800 cotton industry delegates in 2014.

Initiated by the Australian Cotton Growers Research Association (ACGRA), the event is held every two years. Cotton Australia and the Australian Cotton Shippers Association (ACSA) began hosting the Conference in 2010 following the merger between ACGRA and Cotton Australia.

ACSA as co-host added a new level of interest, information and speakers. The conference now covers and represents the entire Australian cotton industry value chain.

CRDC became a foundation sponsor 25 years ago and has continued to grow its support for this vital conduit of information and opportunity for the industry to come together to share ideas and knowledge.

Support for the conference forms an important part of CRDC's commitment to RD&E, as described in its objectives outlined in its first Annual Report in 1990-91.

For anyone who has ever attended, they will agree the Australian Cotton Conference is one of the biggest and brightest around, and with attendance numbers reaching more than 1800 over three days, it is one of the largest agricultural conference of its kind in Australia. In 2014 more than 100 presentations were made to the 1800-plus delegates, with catering reaching a staggering 15,000 servings of food, rolled out to keep everyone well and truly satisfied.

CRDC is proud to be a foundation sponsor and supporter of the conference, which provides a direct conduit for research to growers and consultants, agri-business and from researcher to researcher. It's a one-stop-shop for the latest research and development outcomes and achievements, technology and machinery.

"We are committed to the importance of this event, to ensuring the industry remains cohesive and progressive," CRDC's Bruce Finney said.

"It is organised and run by a committee of dedicated growers, researchers, shippers and representatives from CRDC, Cotton Australia, ACSA and supply chain partners including consultants.

"It is no mean feat to pull together a three-day program to cater for more than 1800 and more than one hundred speakers.

"The work that goes on behind the scenes to make this event run so effectively is commendable and as an industry we are thankful to them for giving of their time and energy."

Darling Downs' cotton grower Stuart Armitage is the current conference chair and says support from CRDC as a foundation sponsor underpins the viability of the conference.

"CRDC's support enables the conference to secure interesting and informative speakers that provide not only great insights to the cotton industry, but also in personal development," Stuart said.

"CRDC's support also assists in allowing us to keep delegate registration rates at reasonable levels - similar conferences held in Australia and globally charge well over $1000 for a two-day line up.

"The conference is well regarded not only within our industry, but internationally and from other agricultural sectors.

"There's no other conference like this within the cotton industry on the world stage – there are conferences specifically for farmers, for merchants and supply chain partners but not an all-encompassing industry event like our very own Australian Cotton Conference, which is testament to the cohesiveness of our industry."

The next conference, including the industry awards dinner, will be held from August 2-4 2016 at the Gold Coast Convention Centre.

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Financial performance over time

The Australian Cotton Comparative Analysis has been compiled independently by Boyce Chartered Accountants since 1984. CRDC began investing in the analysis in 2005 to promote the collation and value of economic benchmarking information for the cotton industry.

The primary purpose of the analysis is to benchmark the income and expenses associated with growing fully irrigated cotton on a per hectare basis – helping growers to identify relative strengths and weaknesses in their enterprises; and to develop budgets and long term business plans for farm profitability.

The reliable, independent figures in the analysis provide the starting point for cotton growers to compare, question, understand and drive improvements to the financial performance of their production.

"Now going into its 30th year, the report provides industry with the ability to analyse trends. We know the range of performance in production, costs and profitability," CRDC's Bruce Finney said.

"For CRDC it's incredibly helpful to understand where in the production system we can focus the most important RD&E to facilitate improvements in profitability."

Paul Fisher of Boyce says having 30 years of data gives the cotton industry perspective in terms of the profit outcome related to physical changes during that time.

"You can effectively overlay profit results on events like adoption of round bale technology, the introduction of Bollgard, GPS, uptake of improved irrigation methods and so on," Paul said.

"Further, you can look at the industry from start to effective 'maturity', and, coupled with other information like asset values and physical indicators such as people, water and horsepower, map out likely scenarios in developing valleys.

"It's the combination of the numbers and the physical information that enables for effective decision making."

Grower-led research

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Encouraging grower associations to instigate local research and development projects has been achieved through the CRDC Grassroots Grants program, introduced in 2011.

Grants of up to $10,000 are offered, with CRDC investing $350,000 in 39 grower-led projects to date across growing regions. CRDC's Bruce Finney says the promotion of local, grower-led research to the greater industry is invaluable.

"These grants provide growers with opportunities for local action and innovation to complement whole of industry RD&E, making beneficial on-the ground gains," Bruce said.

"The grants also have a legacy effect - they provide skills to growers about how to address local issues or needs, improve their capacity to devise and manage projects and offer the option to collaborate with other funding bodies to extend or enhance projects. The positive effects of projects like spray workshops, health and safety or BMP training offer long-term benefits, like practice change.

"A good example of this is Cotton Grower Associations using the funding to install a series of weather stations in a region with the help of other funding, giving broader weather coverage/data, hence better information to growers to base decisions on.

"Meanwhile, the industry as a whole benefits through projects such as managing soil compaction undertaken in the Gwydir Valley, which is a cross-industry issue, with learnings from one region able to be transferred to another.

"A positive flow on benefit has been the number of growers who have become involved in research and development through the grants, and the number of external people introduced to our industry through school and community programs and events sponsored under this program," Bruce said.

A vision for the future

Vision 2029 – Australian cotton, carefully grown, naturally world's best.

Thinking positively about the long term future of the Australian cotton industry in the midst of a record drought and downturn in production is possibly counter-intuitive. But a group of industry leaders saw this as the absolute best time to develop "a shared vision that inspires and unifies the Australian cotton industry" now known as Vision 2029.

In 2009 industry leaders came together through the Australian Cotton Industry Council to develop a plan for the future that could enhance the industry's performance, collaboration and capacity. As a result, the Vision 2029 project commenced and included representatives from these organisations covering the industry from input suppliers through to marketers.

CRDC's Bruce Finney has been instrumental in the creation of this shared industry vision. He says a 20-year timeframe was chosen in order to stretch thinking beyond the short-term and ensure a longer-term strategic focus.

"The Vision's tag line is 'Vision 2029 – Australian cotton, carefully grown, naturally world's best," Bruce said.

"The goal is to reposition the industry in the global marketplace and achieve superior industry performance underpinned by collaboration, the passion and innovative nature of people within the Australian cotton industry.

"Through consultation with industry through stakeholder surveys and scanning activities the trends, assumptions and driving forces that could influence the industry's future were identified.

"Four scenarios were developed identifying possible futures our industry might face: Boom, Bust, Food Replaces Fibre and Present Day Projection.

"From these scenarios the Vision 2029 was developed and more importantly, we identified what the industry would need to be to achieve it."

The Vision 2029 identified that industry needs to be:

- Differentiated - world leading supplier of elite quality cotton that is highly sought in premium market segments.
- Responsible - producer and supplier of the most environmentally and socially responsible cotton on the globe.
- Tough - resilient and equipped for future challenges.
- Successful - exciting new levels of performance that transform productivity and profitability of every sector of the industry.
- Respected - an industry recognised and valued by the wider community for its contribution to fibre and food needs of the world.
- Capable - an industry that retains, attracts and develops highly capable people.

"In the six years since its inception we have come a long way in achieving our goal," Bruce said.

"Industry organisations have aligned their strategic plans with the vision and there has been much progress towards the goal.

"Three examples stand out: firstly Cotton Australia, with the support of CRDC's past and current research, commenced the Cotton to Market strategy in 2014.

"The strategy leverages cotton industry BMP to differentiate Australian cotton directly to brand owners and through partnerships with the Better Cotton Initiative and CottonLEADS program.

"A second related achievement has been the development of the world first cotton industry sustainability report which benchmarks the social, environmental and economic performance of Australian cotton.

"However the best indicator has been the success of growers in setting world record cotton yields in 2014-15.

"Few Australian rural industries are currently achieving annual productivity growth and our results exemplify the commitment of growers to investing in and adopting the results of industry RD&E.

"I feel that in the future people will look back at Vision 2029 as one of our greatest achievements as an industry."

Where to from here?

Cotton RD&E and the next 25 years…

The Australian cotton industry has been a ground-breaker since its first days in the 1960s.

Our pioneers overcame a lack of infrastructure, inexperienced labour, floods, weeds and pest infestations. They could see the potential and knew that help comes to those that help themselves. In this spirit they sought solutions through attracting agronomists, plant breeders, entomologists and other scientists to the fledgling industry.

These foundations of forward looking leadership, tenacity and commitment to R&D-based solutions have been, and will continue to be, important to the success of the Australian cotton industry.

We recognise that we can plan for the future, but that we live in a changing operating environment – and it is not just our ability to identify possible change that is important, but also our ability to respond to these challenges and seize opportunities.

As the industry matures and cotton's place in the textile market evolves, our expectations for R&D outcomes must become more ambitious. We are not only seeking to protect our current competitive advantages of high yield, superior quality and responsible production practices, but most critically, we are also driving profitability through innovation: the application of digital technologies to transform cotton production and supply chains.

Similarly we must look for new competitive advantages for Australian cotton in the face of increasing competition from man-made fibres for market share in apparel. The application of material science and knowledge from unrelated industries could enable the creation of new uses for cotton in high value products such as flexible batteries.

Equally, there are exciting opportunities for introducing open innovation processes and new R&D collaborations with existing and new research partners to ensure we remain at the cutting edge in delivering impact from industry and Australian Government investment in cotton RD&E.

The next 25 years could see our cotton industry entirely transform as we embrace and capitalise on the opportunities, technologies and partnerships ahead. CRDC has started this process through our Cotton Futures program, which invests in progressive, innovative concepts that have the potential to add $4 billion per annum to the gross value of Australian cotton production.

Concepts like agri-intelligence systems, autonomous farming, atmospheric water resources, carbon neutral farming, alternative cotton gin trash uses, dissolving cotton, cotton as a substrate for carbon fibre and using cotton for 3D printing – all potential blue sky concepts that could rapidly change our cotton system.

The future may be complex and uncertain, but, as it was in the beginning, it will be the extraordinary capacity of our people that will keep us on track to achieving the industry's vision for the future.

Spotlight is brought to you by CRDC: the Australian cotton industry's research, development and extension investment body, jointly funded by Australian cotton growers and the Australian Government.

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