CottonInfo

Annual operational plan 2022-2023

CottonInfo is a joint initiative of CRDC CSD COTTON AUSTRALIA

Best Practice


BOSCH

1. Introduction

CottonInfo is the Australian cotton industry's extension program: designed to deliver research and development (R&D) outcomes to cotton growers and consultants and increase the adoption of best practice. CottonInfo is an unincorporated joint venture between three cotton industry organisations: Cotton Seed Distributors (CSD), the Cotton Research and Development Corporation (CRDC) and Cotton Australia. In 2021, the Joint Venture partners renewed the Memorandum of Understanding for the program, ensuring the partnership until at least 2025.

CottonInfo connects growers and consultants with the latest R&D to provide stakeholder input into the R&D process and extend information and technology to help achieve best practice. The team comprises Regional Extension Officers (REOs), Technical Leads and the *my*BMP team. The team works across a broad portfolio covering biosecurity, climate, crop nutrition, disease management, energy use efficiency, fibre quality, integrated pest management, natural resource management, pesticide application efficiency, soil health, stewardship, water management and weed control.

The development of the AOP has three key drivers:

Delivering on the goals and targets of the CottonInfo Strategic Plan 2018-23.

Building on previous extension activities, and considering any opportunities or issues arising from the 2021-22 AOP.

Assessing new CRDC-supported research projects for their suitability to engage with growers and consultants, and integrating these into the AOP.

2. Alignment with the Strategic Plan

The CottonInfo 2018-23 Strategic Plan contains three strategic goals with supporting key focus areas:

Strategic goal one: Successful adaptation and adoption of research and development

A. R&D outcomes adopted to increase productivity and profitability.

B. New technologies and management practices adapted and integrated into best practice in *my*BMP.

C. Supporting cotton farms to be sustainable and maintain their social licence.

D. Collaboration within cotton and across sectors to share knowledge and deliver extension efficiently.

This strategic goal recognises that the outcomes of research are only effective when they result in informed decision-making and practice change in the farming system. The role of extension is to increase the rate of practice change, the reach to more growers and the effectiveness of the change implemented.

Strategic goal two: Enable successful cotton industry expansion

A. A whole of business and systems approach.

B. Support the information and skills needs of new growers and new regions.

This strategic goal recognises that cotton is grown as a component of a farming system, with crop rotations and adjacent land use affecting productivity. Most aspects of farm management are influenced by the wider production system. New cotton growers need to successfully fit cotton production into their farming system as well as grow a profitable cotton crop. CottonInfo will support new growers by connecting them with industry communication channels and existing resources. Peer-to-peer learning will be offered through activities that allow growers and consultants to share their experience. Northern Australia has continued to progress towards the establishment of a northern cotton industry.

Strategic goal three: Prepared to respond to biosecurity threats and assist in the event of natural disasters

A. Capacity to support the industry in the event of a biosecurity incursion.

This strategic goal recognises that the cotton industry needs to continuously plan and prepare for unforeseen crises such as biosecurity incursions. The CottonInfo team provide a foundational asset to industry responsiveness through their established communication systems, both regional and expertise networks, and an understanding of farming systems. CottonInfo will continue to build the team's capacity to respond, develop networks with other biosecurity stakeholders and emphasise the importance of biosecurity plans through *my*BMP.

Our enabling strategies: An effective extension team, and a trusted information source

A. *my*BMP supports and resources industry best practice.

B. Works collaboratively with other industry service providers.

C. Supports innovation and adoption of new technology.

D. Uses innovative communication practices and responsive two-way communication.

E. Is organisationally effective and efficient.

3. The Plan

3.1 Stakeholder engagement

CottonInfo will continue to participate in the Cotton Australia research, development and extension prioritisation process. This provides an industry perspective on grower needs as well as participation in the process of new R&D development.

At a regional level, ongoing coordination between the regional representatives of the partner organisations remains essential. This will continue to be achieved through regular interaction between the CottonInfo REOs, the Cotton Australia Regional Managers (RMs) and the CSD Extension and Development team (E&D team). Each organisation should have an understanding of the work plan priorities of the other, as well as identified areas where they can work collaboratively to effectively deliver outcomes. In practice, this will comprise of a twice-yearly regional meeting between REOs, RMs, CSD E&D Agronomist, regional Crop Consultant Australia (CCA) representatives and the local Cotton Grower Association (CGA) chair to share work plans and identify opportunities to coordinate.

CottonInfo Technical Leads will engage with researchers in their technical area and be the point of contact between relevant research organisations and the CottonInfo team. In conjunction with CRDC R&D Managers, research forums will be supported with the aim of bringing together researchers, industry stakeholders and representative growers and consultants to receive updates of current research and discuss research and extension gaps to prioritise for the future.

3.2 Communications

Led by the CottonInfo Communications Manager, the 2018-23 Communications Strategy is designed to support the CottonInfo Strategic Plan, the AOP, and the CottonInfo team. The primary objectives of the CottonInfo Communications Strategy are to communicate R&D outcomes and extension information to growers and consultants and encourage adoption, using innovative communication practices and responsive, two-way communication; and to communicate CottonInfo's role as a trusted information source to growers and consultants.

Importantly, communications is a whole of team effort. Technical Leads have a key role in working with researchers to package findings into resources and *my*BMP, while the REOs provide direction for regional specific information needs and communicate directly with growers in their region.

3.3 Building upon the 2021-22 AOP

Activities in the 2022-23 AOP that build on 2021-22 activities include:

- Continuing with practical demonstrations of early season retention management. This season will include another round of manual damage treatments of plants in the field to provide visual demonstrations for field days.
- Trials to understand the impact of fallow season optical sprayer residual chemical use on plant-back periods and young cotton plant damage.
- Promoting a second generation silverleaf whitefly (SLW) sampling app, which is expected to include measurement of parasitism.
- Promoting the Sustainability Reporting definition and potential guidelines for soil health.
- Continuing with the four long-term biodiversity monitoring sites that have had a positive management intervention.
- Building on the St George siphonless optimisation trial to extend findings on application efficiency and assess the practicality of efficiency testing process.

3.4 Summary matrix of key activities

In some cases, technical areas will contribute to outcomes and targets across different strategic goals. AOP targets are colour coded to identify alignment with Strategic Plan goals:

Improving rate and reach of adoption and adaptation of research and development
Enabling successful cotton businesses and industry expansion
Prepared to respond to unplanned threats

For each technical area, a Technical Lead and partner REO will be responsible for developing a more detailed activity plan and oversee the delivery of priority activities. REOs will also develop individual action plans that include their contribution to the AOP and regionally-specific activities.

Technical area	Strategic plan targets	AOP targets	Research alignment and collaboration	Priority activities
Soil health	Involvement in three cross-industry projects. Improved yield 11.6 bales/ha. Two farming systems incorporated field days per year per region.	150 growers and consultants participate in systems research tour.	Support from Oliver Knox, UNE Resilient farming systems (Nachimuthu, NSW DPI)	Three soil health workshops, inlcuding in the Namoi, Bourke and Dawson Valley. Promote Sustainability Reporting soil health criteria.
Nutrition	Improved yield average 11.6bales/ha. Improve input efficiencies 11.5kg lint/kg/N. Improve environmental footprint 325kg CO_2e per bale.	Targeting the equivalent of 180kg CO_2e reduction from nitrogen fertiliser, equating to a 30kg N/ha reduction of fertiliser applied.	More Profit from Nitrogen Improving NUE of cotton crops (Baird, NSW DPI) Long-term P decline project (Nachimuthu, NSW DPI)	Continued development of a nitrogen loss warning system using the existing CSD weather network. Nutrition researcher tour of four regions targeting 120 growers and consultants.

Technical area	Strategic plan targets	AOP targets	Research alignment and collaboration	Priority activities
Irrigation / water use efficiency	Improved yield 11.6 bales/ha. Improved input efficiency. 1.3 bales/ML GPWUI. Increasing reliability of production 3.9M bales/year. Five new products supported through testing and validation. Improve environmental footprint 325kg CO_2e per bale.	30% of farms using resources for training of irrigation staff at the start of the season. 300 farms increased awareness of research findings of Smarter Irrigation for Profit research proejcts.	Water productivity benchmarking in the Australian cotton industry Demonstrating and integrating irrigation technology for cotton Climate proofing cotton through improved WUE Limited water systems research Smarter Irrigation for Profit Phase 2 (Rural R&D for Profit program)	Promote findings of the St George bankless trial to other regions. Siphonless irrigation trial continued at St George to investigate a simple way to know when to shut the water off on a bay to improve irrigation performance. Resources provided to farm managers to run irrigation application efficiency training head ditch talks. Four head ditch talks (Macquarie, Lachlan, Gwydir/Namoi and Macintyre) to 40 irrigation staff to improve irrigation application efficiency. Promote CottonInfo Irrigation Toolbox series via newsletters and Cotton Catchups in December 2022 to 600 growers. One Lachlan irrigation management workshop to 10 participants to improve proficiency in irrigation scheduling and water management. Support collection of irrigation benchmarking by helping identify participants (10 per region) for NSW DPI (and data collection if required).
Integrated pest management / area wide management	Improved yield 11.6bales/ha. 3.9M bales 5 year average production.	Minimum of three Cotton Catch-up meetings in each valley targeting 20 growers and consultants per meeting. Insect resistance monitoring projects supported.	IPM for high yielding cotton Improved management of SLW Supporting farming systems adaptation to climate and biological pests Sensors for IPM Developing proactive approaches to IPM Novel options for IPM	Early season cotton catch-up farm walks in all regions to focus on implications of last season's retention trials. Crop checks published fortnightly during the season in all regions and distributed to consultants, researchers and industry. Continuing on-farm demonstrations of recovery potential from early retention loss in six regions. Promote SLW app.

Technical area	Strategic plan targets	AOP targets	Research alignment and collaboration	Priority activities
Disease	Improved yield 11.6 bales/ha. 3.9M bales five-year average production.	FUSCOM seminar delivered to 50 participants. Early and late season disease surveys completed and results extended regionally to all growers. Verticillium management trials, looking at soil inoculum levels (pre and post crop) on two farms.	Industry disease surveys (QDAF, NSW DPI) Disease suppressive soils Using DNA diagnostics to monitor disease suppressive cotton systems Innovative solutions for disease Tactical management and surveillance of Verticillium, Fusarium and reocurring wilt CSD, QDAF, LNCGA	Organise FUSCOM to provide a platform for sharing current research and identifying priorities for disease research and extension (face to face in September 2022). Participatory research on disease in three regions. This will focus on farm research monitoring and evaluation of disease levels. Continue the verticillium rotation and management trials with CSD and in partnership with the Lower Namoi CGA and QLD DAF in the Macintyre.
Weeds		Establish three experimental sites with a combination of best practice weed management strategies based on HRMS and modelling.	AWM for cropping systems weeds Regional demonstration of integrated weed tactics across farming systems Integrated weed management Improved management of weeds in cotton and grains farming systems Regional approach to weed management, focus on sowthistle and annual ryegrass, Koetz & Charles, NSW DPI, Werth, QDAF	Regional surveys of the top five resistant weeds in 50 fields to keep awareness of changes in resistance. Three on-farm herbicide option demonstrations with a field day and additional farm walk at each during the season (targeting 75 participants).

Technical area	Strategic plan targets	AOP targets	Research alignment and collaboration	Priority activities
Biosecurity	Participate in two industry training exercises. 30% farms with a documented biosecurity plan.	30% of growers having a current written biosecurity plan.	*my*BMP Biosecurity module updated Collaborate with Cotton Australia Regional Managers	Biosecurity/*my*BMP Biosecurity Module workshops to develop farm biosecurity plans for 50 growers.
Stewardship		85% growers and consultants use the IRMS when making spray decisions. All regions contribute to insect resistance monitoring. Stewardship of Bt technology is of high importance to 90% growers.	Insect resistance monitoring (SLW, Mirids Mites Aphids Thrips) Improved management of SLW Heliothis resistance monitoring	Promotion of stewardship in Bt and of insecticides. REOs have continued involvement in insect resistance monitoring programs. Communication of resistance issues.
Spray drift		Spray drift awareness support for the Spray Drift Working Group. All CSD distributing agencies provided information.	Understanding motivational factors of spray application Inversion tower network Business Research and Innovation Initiative (BRII) projects (LX Design House and SwarmFarm Robotics)	Work with spray drift working group. Distribution through CSD reseller network. Support the successful BRII projects to develop innovative options for eliminating spray drift. Support SOS (Stop Off-Target Spraying) group activities – assisting with comms and awareness. Promote the CRDC GRDC hazardous weather warning system to improve on farm decision making. Awareness and promotion of emerging technology.

Technical area	Strategic plan targets	AOP targets	Research alignment and collaboration	Priority activities
Natural resource management	Increased capacity to manage natural capital 6.6% native veg managed for conservation.	Increase 200 growers' and consultants' awareness of *my*BMP guidelines for conserving biodiversity on cotton farms.	Landcare Tech-Innovations projects Managing natural landscapes on Australian cotton farms to improve natural capital and increase the provision of ecosystem services. Managing riparian corridors on cotton farms for multiple benefits. A scoping study on impact of irrigation infrastructure on native fish (Hutchinson)	Four long-term biodiversity monitoring sites continued. Sites will be used as case studies for biodiversity communication. 90 growers and consultants participating in NRM extension events Extension of fish entrainment R&D outcomes to growers. Three biodiversity management field day (kayak trips) at St George, Boggabilla and Moree in September 2022 targeting 50 growers to improve knowledge and skill in managing native vegetation on-farm and increase their understanding of the benefits to their cotton production system.
*my*BMP	100% modules updated with CRDC research. 50% growers completed level 1.	Increase certified farms from 313 to 380 (2023 growing season).	CottonInfo team in collaboration with Cotton Australia Regional Managers.	Encourage *my*BMP participation through all extension activities and CottonInfo communication material. All modules reviewed in the 12 months to prioritise updates with Technical Leads. Continue to develop international recognition of the *my*BMP brand and sustainability. *my*BMP biosecurity webinar aimed at building the capacity of REOs and CA Regional Managers to enable them to work with growers on managing biosecurity risks.
Industry expansion	Economic partial analysis of energy, nutrition, irrigation and pest management completed. 90% of new growers actively supported in their first season.	90% of new growers supported.	Supporting cotton in Northern Australia	Support new growers with resources, farm walks and peer-to-peer learning. Review of *my*BMP for Northern Australia. Coordinate activities with CSD E&D and Bayer Territory Business Managers.

Technical area	Strategic plan targets	AOP targets	Research alignment and collaboration	Priority activities
Fibre quality		Quantify the impact of limited irrigation on fibre quality. Results communicated to 80% growers. Assess the impact of nitrogen fertiliser rates on fibre quality and lint turn out.	Maintain and improve Australian cotton fibre quality Defoliating cotton in a difficult environment	Reporting on comparison of spindle vs stripper harvesting on semi-irrigated cotton. Contributing key messages on N impact on fibre quality from analysis of CSIRO N trials. Establish the impact of harvesting and ginning on seed damage and the creation of seedcoat fragment levels.
Energy and business	Improve environmental footprint 325 kg CO_2e per bale. Economic partial analysis of energy, nutrition, irrigation and pest management completed.	To lower energy costs in the cotton system and simultaneously lower emissions per bale to 360 kg CO_2e One partial budget to support extension delivery.	Understanding environmental impacts with changing demand for cotton Climate and energy for cotton farm businesses	Work with the Agriculture Innovation Australia Climate Initiative Baselines and Beyond project. A technical area will be selected to develop partial budgets.

3.5 General targets

In addition to the specific targets outlined above, there are a number of general targets in the CottonInfo Strategic Plan that need to be addressed in the 2022-23 AOP, as follows:

Target: 10 new projects with adoption pathways that include CottonInfo annually

2022-23 activity: Implement the outcomes of the cross-RDC Better integration of extension into research project. The target projects for adoption pathway development will be finalised when contracting timing is completed with CRDC. While CottonInfo has a process in place for developing adoption pathways for individual projects, we are looking at transitioning to program level adoption pathways to better align with CRDC research management.

Target: 200 extension activities delivered. 85% of participants report an intention to change

2022-23 activity: With restrictions from COVID reducing, the CottonInfo team will aim to deliver over 50 extension activities impacting more than 1000 participants.

Target: 85% growers with devices linked to the office

2022-23 activity: CottonInfo will work with digital agriculture providers, such as CSD's CottonTracka, and continue to build team capacity in using digital tools to support individual grower on-farm trials. Digital tools provide a significant opportunity for growers and consultants to test management options, improve farm efficiencies as well as providing new opportunities for extension to support informed practice change.

3.6 Team skills development

A significant opportunity to increase the impact of extension is to better use digital technology to enable action learning on-farm. The ability to use remote sensing to automatically collect data and improve data analysis options is opening the door for growers and consultants to run trials with less time and effort. CottonInfo has started the process of engaging with digital agriculture providers (such as PCT, Goanna Ag and John Deere) to work with them to build the team's capacity to harness this technology.

3.7 Evaluation

CottonInfo's impact is measured through monitoring and evaluation (M&E), guided by the CRDC M&E Strategy. The purpose of the strategy is to demonstrate the extent to which CottonInfo has contributed towards the specified targets within the CottonInfo Strategic Plan. It also helps guide future strategic priorities, activities and provides timely feedback to understand barriers and any unintended consequences of extension adoption.

It is a continuing challenge to measure and report on the impact of extension activities. Strategies include asking for feedback on intention to change at the time of the activity, following up with growers at a later date to record actual changes and utilising industry surveys to follow general trends in practice. We are working with the CRDC M&E Manager to improve the mechanisms of monitoring and reporting evaluation. This includes set templates for data gathering and use of PowerBI for reporting.

3.8 Integration of H.A.R.D. research projects

Each year, new CRDC R&D projects are assessed for their suitability to engage with growers and consultants. CottonInfo uses a four point H.A.R.D. assessment of projects to see if they require **help** from the team, should be part of an **awareness** campaign for end users, are a **resource** providing expertise or key knowledge, or if there is a specific regional **demonstration** associated with the project. These projects meet the Strategic Plan target of 30 H.A.R.D. projects integrated into the AOP (★ denotes a new 2022 project).

3.8.1 Plant nutrient management and soil health

D: RDP1712 More Profit from Nitrogen (Schwenke, Baird, Antille)

Timeframe: 2016-21

Issue: Seasonal nitrogen (N) losses from cotton systems can be as high as 50% of the N fertiliser applied. Nitrate denitrification in anaerobic soils is likely to be the main N loss pathway, although ammonia volatilisation and nitrate leaching may also be significant loss pathways in specific situations. Farmers need to know what these high risk situations are and what the potential for loss is, so that their N inputs may be more efficiently managed.

Outcomes:

1. Accounting for SOM mineralisation and starting soil mineral N is critical to optimise N application rates.
2. Split and or in-crop application of N did reduce field N losses compared to applying all upfront but there is higher potential of greater residual N post-crop.
3. Drilling N in-crop had highest crop N uptake, had less losses and had greater residual N post crop.
4. EEF products did reduce field losses of N but had limited impact on yield.
5. Applying P fertiliser with N did improve yield and reduced the P decline in cotton systems.

A: CSP1904 Improving nitrogen use efficiency (Antille)

Timeframe: 2018-22

Issue: Traditionally, it has been assumed that N is only available for uptake when in the mineral (i.e. ammonium or nitrate form); accordingly organic N has not been considered an important source of N. In light of continued results from work done in cotton that demonstrate the importance of soil mineralisation to total plant N uptake, and recent research in other areas that highlights that dissolved organic N is an important source for plants, it is important to develop a better understanding of the role of organic N in cotton farming systems, and how to potentially manage it better.

Outcomes: The project is quantifying the uptake of dissolved organic nitrogen in different cotton varieties in high yielding systems. It is addressing :

1. The importance of the dissolved organic nitrogen (DON) pool relative to nitrate and ammonium for cotton nutrition.
2. The impact of soil type on uptake of dissolved organic nitrogen relative to nitrate and ammonium for cotton nutrition.
3. In high yielding soils does the dissolved organic nitrogen pool influence fertiliser nitrogen use efficiency?
4. Is uptake of DON a general phenomenon in cotton or is the relative uptake of NO_3-, NH_4+ and DON variety-specific?

R: QUT1902 Future Farming phase 2: Improved confidence in targeted N management (Grace)
Timeframe: 2018-22
Issue: CRDC, in partnership with the Grains Research and Development Corporation (GRDC), is investigating the opportunities to optimise nitrogen use efficiency through automated sensing, decision-making and deployment. The first phase of the collaboration is reviewing current state-of-the art technology relating to sensors (acquiring the data required to make better N management decisions); decision support systems (algorithms currently available that can analyse the information from the sensors to provide a management recommendation); and the technology available that could implement the management recommendation.

Outcomes: This research is improving the way soil and crop sensors are used to inform decisions about input management and provide a way of automating the process from data acquisition, through analysis, to the formulation and implementation of decision options.

R: AE2201 Driver and limitations of practice change for nitrogen management (Welsh)
Timeframe: 2021-22
Issue: Despite ongoing investment into nitrogen use efficiency research and extension, industry-wide nitrogen application rates have not trended down towards recommended rates. To determine the next steps for nitrogen research, understanding industry behaviour and attitudes towards nitrogen application rates is key.

Ag Econ has conducted a preliminary investigation into the drivers and limitations of practice change in terms of nitrogen budgeting for the Australian cotton industry (both farmers and advisors).

A: Closing the loop: textile waste composting (Palanisami) ★
Project timeframe: 2022-23
The compostability of cotton fabric is a potential means of creating a circular system of cotton production, allowing growers to return carbon to the soil and potentially benefit soil health and functionality as well as create a sustainable method of end-of-life management for cotton clothing or waste. This is also an exciting marketing angle for the cotton industry as a whole. Currently there is no established method for composting cotton fibre, and its effects on soil health and functionality is unclear. This research could facilitate a means of increasing soil carbon and give growers a method of carbon sequestration on farm, although the amount of carbon that could be sequestered this way and its potential longevity in the soil is unclear.

This project will determine a method for composting cotton fibre, assess the impact of composted cotton fabric on soil health and functionality, and assess the potential for composted cotton fabric to increase soil carbon and microbial activity.

A: Validation of soil testing guidelines and critical values for nutrients (McLaren) ★

Timeframe: 2022-25

Modern cotton varieties grow differently to the historical varieties that were used to calculate critical soil test results for some nutrients. Modern varieties are higher yielding, have higher retention rates driving demand early in the season, and can produce significant biomass. The industry is seeking to understand if the current critical limits for nutrients are accurate in terms of the demand and pace of demand for some nutrients, which may be driving down the reliance on soil testing as a decision support tool for fertiliser decisions. This project will inform our understanding of plant demand and ensuring growers have the right tools for assessing their soils. Leaf testing is becoming more and more important as a tool for assessing plant nutrient stress during the season, and calibrating this with soil testing would provide another tool for growers to make timely and accurate nutrient assessments of their crops.

CottonInfo Activities in 2022-23 to connect growers with this research include:

- Field days/workshops (max 6): 3-4 NSW and 2-3 QLD (these will align with areas that are new or haven't been visited for a period of time (such as Bourke and Hillston)).
- Workshop handout booklet containing abstracts from researchers attending and promotion of CottonInfo resources.
- Updating images of nutrient deficiency symptoms, which can be incorporated into publications and information sheets.
- Grower case studies of nitrogen inhibitors/coatings.
- Denitrification warning systems - develop a platform that advises growers when conditions are favourable for N fertiliser application.

3.8.2 Water use efficiency

R: RRDP2002 Real time automation for irrigation (Foley)
Project timeframe: 2020-23
Issue: This project is understanding and addressing the barriers to widespread adoption of automated irrigation in the cotton industry. This includes the components for a 'market ready' precise automated irrigation system for Australian farms; a capacity building program to increase irrigation engineering capability available to assist growers in the design improvement of pumped pipeline and surface irrigation systems, and demonstration and extension of precise autonomous irrigation systems.

Water access and irrigation labour availability are significant factors that influence irrigation system selection. USQ with CRDC and Rural R&D for Profit funding have developed automated, site-specific surface and pressurised irrigation systems. These systems integrate software and hardware including low cost sensors, optimisation control software (VARIwise) and actuation systems to automatically analyse field data and implement site-specific irrigation. This project is continuing the focus on developing and demonstrating commercial scale precise automated broadacre irrigation systems across furrow, centre pivot and lateral move irrigation.

A: RRDP2007 Evaporation mitigation solutions (Qiao)
Project timeframe: 2020-22
Issue: Evaporation is the greatest loss of water from Australian cotton farms. To tackle this problem the Australian cotton industry has previously invested in the evaporation mitigating technologies such as monolayers and commercially available plastic balls.

Outcomes: This project is an approach combining development of new formulations with a mechanical engineering approach to reduce wave action. The next step in the advancement of successful monolayer technology is to build on the findings of a recent project and develop and demonstrate the effectiveness of a new generation of monolayer materials and associated engineering solutions which provide increased resistance to wind (>3 m/s), enabling greater water savings.

A: UWS2201 Climate proofing cotton through improved WUE (Sargent) ★
Project timeframe: 2022-25
This project will generate knowledge around abiotic stress physiology to protect Australia's cotton production under future climates; specifically severe and frequent heatwaves and droughts.

The research seeks to identify novel heat tolerance and water conservation mechanisms existing in cotton and its wild relatives. The long-term objectives are to redesign cotton photosynthetic biochemistry to enable the cotton industry to withstand environmental extremes and improve resource-use efficiency (nitrogen and water). This will be achieved through the identification of photosynthetic traits which may be used in climate-adapted variety development programs.

H: DAN2203 Limited Water Decision Support (Dadd)
Timeframe: 2021-24
This project is assisting growers who face limited water situations. The project is developing case studies of innovative practices used by cotton growers to maximise productive and profitable water use in limited water and partial irrigation scenarios. This will include bales/ML and gross margin/ML measures. It will also improve our understanding of the relationship of actions, decisions and management strategies on water productivity and profitability. This project will review past research, and engage with industry to develop case studies and/or scenarios to demonstrate the effectiveness of different limited water management strategies to maximise $/ML. This will be extended to industry through demonstration trials, development of extension resource and/or decision tools. The project will also make recommendations to industry about research gaps and opportunities to improve water productivity to address this goal.

D: Demonstrating and integrating irrigation technology for cotton (Foley)
★
Project timeframe: 2022-25
With a number of technologies now available to support sensors, irrigation scheduling decisions and automation there is increasing complexity in systems integration. This investment will enable on farm technical demonstration of irrigation technology and best practice. This provides an opportunity for new technologies to be independently assessed as well as enable extension/adoption activities to support growers to understand how water use efficiency research and technology can be applied to their systems. Integration of irrigation technologies has been identified as a barrier for adoption of irrigation ag tech and in addition to demonstrating individual technologies this project will develop understanding about potential integration of different technologies.

A: Optimising irrigation performance in bankless systems (Quayle) ★
Project timeframe 2022-23
Bankless channel or siphonless irrigation systems are rapidly being adopted to address labour availability and energy use challenges. While general best practice principles for optimising these systems have been applied, questions remain on optimisation (uniformity, management of tailwater). This investment will assess and investigate best practice for optimising irrigation and nutrition for bankless systems. The project will incorporate ag tech and link to demonstration sites and extension activities.

A: Measuring evapotranspiration from canopy temperature (Kelderman) ★
Project timeframe: 2022-23
This post-doc project will continue the technology development of a novel, low-cost system that determines crop evapotranspiration (ETc) from its canopy temperature. The so-called Canopy Temperature EvapoTranspiration (CTET) system was demonstrated to be accurate against precision, high-cost, micro-meteorological instrumentation in irrigated cotton fields near Wee Waa in full-plant, single-skip and bare earth scenarios during the 2018/19 and 2019/20 seasons.

CTET repeatedly solves a complex mathematical model that uses canopy surface temperature and other meteorological inputs to determine the rate of evapotranspiration (ETc). It is significant that all data for CTET is measured at the field and does not rely on any off-site data sources. A CTET system can be used to give an indication of how much irrigation needs to be applied to restore soil moisture to field capacity based on accumulated ETc. (This contrasts with canopy temperature stress systems which uses canopy surface temperature to determine crop stress and so indicate when to irrigate.) A remarkable feature of CTET is that it remains effective and accurate even if exposed soil is within its field of view; indeed, evaporation from fallow fields can be measured using CTET.

R: Water productivity benchmarking in the Australian cotton industry ★
Timeframe: 2022-25
The Australian cotton industry experiences seasonal variation in water use, but has a long term trend of reduced water use and increased water efficiency per bale. To address social license expectations and support industry sustainability reporting there is a need to assess industry water use.

As part of industry's commitment to sustainability reporting, this project will independently measure and report water use efficiency in the cotton industry including exploring opportunities to use remote sensing and existing grower and industry data to automate industry benchmarking and support growers to identify areas for improvement. In addition to reporting on irrigated cotton water use productivity metrics, the project will also report on industry's dryland water productivity metrics (expected to be finalised by June 2022). This project will also investigate potential collaborations with broader cross industry initiatives for whole of farming system water productivity.

CottonInfo activities in 2022-23 to connect growers with this research include:
- Industry Gross Production Water Use Efficiency measured on a minimum of 10 farms in each cotton region.
- REO training to understand WUE benchmarking data collection.
- Trends and Drivers project results presented at Cotton Catchup meetings.
- Head-ditch talks (location based on region demand).
- Irrigation Toolbox Series promoted in Regional Newsletters in November/December.
- A customised irrigation workshop for the Lachlan Valley.
- Promotion of the St George siphonless optimisation trial of 2021-22 and support for a potential new trial in 2022-23.

3.8.3 Farming systems

A: CRDC2202 Building profitable farm systems through increasing soil carbon (McCaffrey)
Project timeframe: 2021-23
This project aims to develop a vision of future dryland cotton systems. There is a need to integrate and build on the current knowledge to support understanding and decision making on to how to optimise different tactics under different scenarios and in different regions. Growers need to know how manipulation of their system can build carbon levels through sustainable farming practices and improve water use efficiency.

Outcomes: Cropping systems tactics and recommendations for future resilient farming systems will be developed and extended through field days, demonstrations and industry forums on the back of the following outputs.
A review of work to date on optimal farming systems components including cover cropping, water use efficiency and measuring soil carbon to determine which systems may hold benefits for the future.

The project will produce case studies of growers using innovative farming system practices, for example; cover cropping, soil carbon sequestration, and innovative pest control methods. It will conduct demonstration trials displaying innovative farming systems tactics as identified by the review and case studies. It will conduct economic analysis of the profitability and water use efficiency of potential systems and evaluation of commercial soil carbon accumulation projects.

R: CSP2001 Modern systems agronomy for resilient cotton production (Broughton)
Project timeframe: 2020-22
Issue: Increased climate variability and climate extremes such as hotter maximum temperatures, longer dry periods and increased storm intensity will increase the stresses of cotton production and increase the risk of fruit losses, and reductions in yield and quality. Novel management tactics are required to combat the anticipated increased frequency and scale of these stress events.

Outcomes: This project is developing new tactics or technologies for reducing impact of shedding particularly during periods of plant stress (e.g. low radiation, high heat, water stress) and/or development of new tactics or technologies to control boll opening; development of supporting digital data collection and analysis technologies to support management decisions for managing and/or mitigating abiotic stress.

In addition, to ensure good coverage of issues raised by growers, the project is also examining improving yield through better management x climate x physiology, including revisiting row spacing, and planting density, for Bollgard® varieties.

H: DAN1801 Resilient farming systems in irrigated vertisols (Nachimuthu)
Issue: Understanding the causes of yield variability (within and between fields) and identifying the appropriate management strategies to address them will result in improving yield in low-yielding areas, and thus overall average yield and profitability. While soil constraints and variability may explain some of the variation in yield, there is no easily-adoptable framework to assess the core factor(s) causing the variability. This project has sought to identify the causes of yield gaps in several locations. This has helped inform a framework for growers, consultants and Regional Extension Officers to systematically diagnose the factors, and asses their relative significance and contribution to yield variability.

Outcomes: Through a strong regional focus on field trial-based collaboration with the REOs to help ensure local applicability and relevance of project outcomes, this project will seek to develop a framework that will support growers, consultants and REOs to more easily identify the reasons behind yield variability, the relative contributions of the reasons, and thus the priority management interventions required to close the yield gap.

A: CSP1903 Science leadership for Northern Australia – supporting the development of cotton in the farming system in Northern Australia (Yeates)
Project timeframe: 2018-22
Issue: Cotton expansion in Northern Australia has unique challenges and risks. While extensive research has been conducted, there is limited cotton production experience in the region. There is also a need to ensure crop modelling reflects the broad range of potential new regions and any proposed developments are based on the best available science for cotton.

Outcomes: Continue existing and develop new RD&E partnerships with organisations (commercial and Government) intending on investing in new cotton regions and continue to provided agronomic and technical support for commercial and government activities / enquiries regarding cotton production in northern Australia and other new production areas. The project will produce economic assessments that link with biosecurity and environmental considerations.

A: CQU2201 SHIFT: Best practice to manage future workforce skills (McDonald)
Project timeframe: 2021-24
Issue: Attraction and retention of a skilled workforce is a major issue for the Australian cotton industry. This project is examining what on-farm training looks like (on the job training, interactive staff reflection, mentoring, formal training and extension information sessions) and how cotton growers can influence strong technical skills in their farm workforce and prepare staff for future changes to their jobs that are driven by the introduction of new technology.

Outcomes: This project will develop practical tools and test these tools through the *my*BMP program to assist cotton growers and their employees have effective workforce management on cotton farms
It will provide an understanding of how cotton growers provide on farm training to staff and develop practical tools to assist training of skills on farm. It will also provide a framework for growers and employees in adoption and implementation of new technologies on farm including the new technology introduction, transition and maintenance periods.

A: CRDC2113 Ensuring best practice is based on science (Cosgrove)
Project timeframe: 2021-24
Issue: Australian cotton production needs to ensure it is addressing sustainability issues to maintain its social licence to operate. Innovative and collaborative work is under way to develop consistent ways of measuring and setting targets for cotton farm greenhouse gas emissions, biodiversity and soil health.

Outcomes: Draft five-year targets for most priority sustainability topics have been developed with progress towards these targets monitored. Stakeholder engagement and materiality assessment processes are put in place to identify and prioritise sustainability opportunities and risks. Systems are implemented to appropriately respond to priority sustainability topics, via existing industry research (CRDC), engagement (CottonInfo), best practice (*my*BMP) and advocacy (Cotton Australia) structures.

R: Benchmarking soil carbon, soil properties and management of long term trials (Nachimuthu) ★
Project Timeframe: 2022-25
Past research conducted in Australian cotton farming systems has shown soil and crop management influenced the soil organic carbon (SOC) changes and minimised carbon losses. More recently, the SOC concentrations across selected on-farm cotton industry sites were lower than research station fields. This suggests that either there is a potential for minimising the SOC losses or improving the SOC across the industry fields by manipulating the cotton cropping systems and by improving our understanding of post sequestration losses. Benchmarking SOC in conjunction with soil and crop management over time will assist with identifying the climate-resilient cotton cropping systems. In view of this, the project aims to:
1. Benchmark SOC between long term trials and selected on-farm industry sites.
2. Benchmark soil properties and soil management between long term management systems and selected on-farm industry sites.
3. Investigate and identify the soil management and novel crop rotation tactics that minimise the SOC losses and sustain/improve SOC and soil physical properties in modern cotton farming systems.

H: How to attract and retain young people on cotton farms (McDonald) ★
Project timeframe: 2022-25
The sustainability of cotton farming relies on young people wanting to work or invest in the cotton industry and regional communities. To ensure the growth of the cotton industry it requires an understanding of the pathways that attract, retain and develop its workforce. Australia agriculture is changing and so are its career opportunities; from the impact of technological innovation, to changes in climate and fundamental changes in regional communities (loss of rural residents, liveability, isolation and an aging agricultural workforce). This is impacting the availability, skill level and competition of labour in regional cotton communities.

The project will examine attraction and retention of young people on cotton farms, with a focus on young people's experiences and career pathways. How well are people retained? What influences this? How well people are retained contributes to profitability. The study will identify gaps and areas for intervention and change with young people and key partner organisations.

A: Seeking regionally specific guidelines for cover crops (O'Donoughue) ★

Timeframe: 2022-25

Cover crop types, their management and the reasons behind planting and managing them range between regions, soil types and climates. Feedback from several regions has indicated that there are research and extension questions and needs in specific areas. The range in questions being asked by growers, and factors affecting decisions around planting and management of cover crops lends this topic to a two-fold approach. First, there are research questions about the best crops to use, and what the multiple benefits to soil and water management might be. Second, there is an extension and on-farm research program requirement, using standardised measurements and assessments of various cover crops being used on farms throughout the industry. These could be used as case studies, and to evaluate in a consistent manner what did and didn't work, and the extent to which various desired and extra benefits were realised.

This will require a research component, and collaboration with CottonInfo work on cover crops already underway. The project will need to work closely with CottonInfo to develop assessment criteria for commercial cover crops, as well as providing the support to collect and analyse the data.

R: Supporting southern cotton production systems (Shakeshaft) ★

Timeframe: 2022-25

The cotton industry in southern NSW expanded from relatively small areas less than a decade ago to a key part of the Australian industry. Addressing emerging issues such as IPM, disease and fibre quality is important in ensuring the Southern system remains sustainable and the production system is reliable. This project will develop a research program to develop clear and quantified strategies for cotton in southern regions to continue to optimise seedling establishment and improve crop agronomy for optimised yield and fibre quality, while providing capacity to respond to emerging issues.

3.8.4 Integrated Pest Management

R: DAQ2201 Supporting farming systems adaptation to climate and biological pests (Grundy)
Project timeframe: 2021-24

IPM & Biosecurity
Over the next five years, the direction of IPM and biosecurity preparedness for the cotton industry will be influenced by increased chances of pest incursion, restriction or loss of insecticides due to Government regulation and an increased proportion of growers/advisors that are either new to cotton (or have only ever known the simplicity of Bollgard® production), leading to a discernible loss of background awareness regarding hard won IPM or biosecurity gains.

Working with CottonInfo, Paul Grundy and Sharna Holman are enacting a targeted extension program to ensure growers and their advisors have access to current IPM, stewardship and biosecurity preparedness practices and are first responders for emerging IPM and biosecurity issues. Specific support for growers and advisors in northern Australia (NQ, NT and WA) will be provided, as the pest management and biosecurity challenges in these emerging industry tropical regions differ from the south. Leadership and direction will also be provided for various industry panels within relevant technical areas (TIMS, Biosecurity) in conjunction with CA and CRDC.

An extension program with CottonInfo to better educate growers and advisors on aspects of crop growth and development, response to damage, and yield development will also be enacted. Sound recommendations for early season fruit management in cotton that accounts for productivity, economic and sustainability factors will be developed.

Defoliation
Defoliation difficulties requiring increased chemical application have in turn exacerbated off-target impact risks. A preliminary assessment using records from long-term CSD variety trials suggest that a combination of agronomy, plant and climate factors are contributing factors as well as defoliation techniques. An integrated approach managing these factors is more likely to deliver improved leaf drop, boll opening and regrowth prevention.

Given that chemicals have not changed, defoliation difficulties are likely due to factors such as soil status (nitrogen and water), field conditions, variety type and the timing of defoliation commencement. It is proposed that a stepwise approach be taken to review and better understand constraints to identify which factors have the greatest influence, followed by testing strategies that may overcome identified limitations. A key focus will be to improve extension information related to defoliation practices.

(*Continues next page.*)

Spodoptera litura
Wet season-sown cotton following the release of Bollgard II® was tested between 2007-12 (CCC CRC and CRDC) in the Burdekin, and found to produce higher yields with excellent *Helicoverpa* control. *Spodoptera litura* was frequently survived in these test crops, but lack of industry development left the issue unaddressed. With recently successful wet season cotton production throughout northern Australia (26,000ha in 2021) and gin construction, the cause of regular *Spodoptera* survival in tropical Bollgard® 3 crops must be understood so appropriate strategies mitigating the potential for resistance can be established. The current RMP ignores *Spodoptera*, posing a substantial unresolved risk for sustainable Northern Australia industry development.

The research component of the project aims to develop data that would help underpin a management strategy *S. litura* in Northern Australia. Research will determine:
- *S. litura* ecology and key mortality agents within tropical farming systems.
- Adaptations that may advantage *S. litura* survival on Bollgard® cotton crops.
- Environmental and plant factors that might increase survival on Bollgard® crops.
- Damage potential of *S. litura* to inform in crop management.
- Suitable refuge crops for the complex of caterpillar species in Northern Australia.

Central Queensland
Late winter sowing has transformed cotton production in CQ and encouraged renewed thinking about how cotton could be better grown in a changing climate. A previous project also identified that Helicoverpa population dynamics have changed markedly since the introduction of Bt cotton and that the Bollgard RMP must seek to better mitigate resistance risks, particularly if alternative production strategies are adopted locally. Adapted techniques such as early winter cotton, double picking and grown-on cotton may potentially increase yields by >50%, but this is unlikely to be sustainable without appropriate pest management and farming system adaptation. CQ's unique environment provides an opportunity to further explore adapted crop production techniques that are highly relevant for hotter production areas both south and north.

Research will be conducted to test and validate adaptive cropping options (winter sowing, double picking and early sown-delayed pick). Farming system and pest management factors for prospective tactics will also be assessed for consideration prior to industry adoption and to allow RMP risk modelling by Bayer. Growing short-term cover crops to improve system sustainability will be explored (Central Highlands and Dawson) as part of a package of tactics that aim to support maintenance of yield potential for high yielding crops.

A: NEC1901 Sensors for IPM (McCarthy)
Project timeframe: 2018-22
Issue: The ability to accurately assess pest and beneficial populations, as well as plant growth/damage, is key to making good integrated pest management (IPM) decisions.

Outcomes: This project is developing a machine vision sensing approach able to discriminate pest infestations to enable efficient strategies for pest management. Discrimination will be through the differing characteristics of the pests, their by-products or plant response. The development of the proposed sensing system will improve the accuracy of pest detection, and increase sampling efficiency. This information could enable management decisions to be made at the correct time according to existing threshold models. There is potential to combine the data from multiple sensor users to improve tactics for the area wide management of pests, management of resistance and feedback on the efficacy of deployed control tactics.

R: CSP2203 Developing proactive approaches to IPM (Heimoana)
Project timeframe: 2021-24
Issue: This project is developing alternative, IPM-friendly management options for mirids and other cotton pests including green vegetable bugs, soil pests and mealybugs. It is also collecting information on pest and beneficial activity and developing new technologies for pest monitoring, which will support new IPM strategies and technologies. The impact of pesticides on beneficial insects is an important component of a pesticide selection decision, and this project will support the independent assessment of new pesticides on beneficials.

Outcomes:
1. Pesticide targets – analyse the factors which drive the insecticide components of Environmental Toxic Load, the future risks associated with current insect control practices and R&D (including digital approaches) required to overcome them.
2. Mirid management – synthesise past research and current management across cotton and other crops; explore the value of historical data in predictive modelling around forecasting incursions, and identify potential future R&D on alternatives to current insecticide-based practices for in-crop management.
3. Impact of insecticides and miticides on predators, parasitoids and bees in cotton – assess the value of work to date (economic impact analysis), its potential application across commodities and identify research partners and contributors who may benefit from this work.

R: DAQ1903 Improved management of silverleaf whitefly (Sequeira)
Project timeframe: 2018-22
Issue: Silverleaf whitefly is a serious pest for the industry. Consultants have reported that the current silverleaf whitefly sampling and matrix do not deliver consistent results across seasons and regions. Recent sampling has confirmed the need to review and update management recommendations for this pest.

Outcomes: Improved decision support package for SLW including sampling, threshold and role of insecticides and updated industry IPM.

H: CCA2201 Novel options for IPM
Project timeframe: 2021-22
Issue: This project is a collaboration between Crop Consultants Australia (CCA) and IPM Technologies to research and implement new Integrated Pest Management (IPM) strategies. CCA is the professional association of cotton and broadacre agronomists in QLD and NSW. IPM Technologies is a Victorian-based company that brings a new perspective to the cotton production system. A participatory research approach will be used to adapt and improve current pest management and monitoring techniques, and the impacts of these and future technologies on beneficial insects.

The CCA network of agronomists and their growers will be used to workshop IPM strategies. This process will tailor the research to allow for regional differences between valleys.

The project is focusing on conducting an industry-wide review of the management strategies for all insect pests in cotton. The workshops will be the starting point, and this will be built on through a follow-up process of consultation with the entire industry. This comprehensive review will include growers, agronomists, researchers, policy makers, industry service providers, processors and the broader community.

A: CSP2204 Validation and implementation of new molecular tools for BT resistance monitoring (Downes)
Project timeframe: 2021-24
Issue: This investment will support a partnership with Bayer and CSIRO to continue research on Bt resistance. This will build on a previous CSIRO project that is expected to deliver a molecular approach for F1 and F2 resistance testing. The higher throughput system provides the capacity to test for a greater number of individuals, improving efficiencies and gaining the power of large numbers to statistically analyse populations. This second phase will focus on the validation of the molecular tool for F1 and F2 resistance testing, use the tool to evaluate the existing resistance management tactics in the RMP and investigate this approach to monitor other species (*Spodoptera litura* – cotton leafworm and *Spodoptera frugiperda* – fall armyworm).

Outcomes: The project will validate the molecular tool for F1 and F2 resistance testing and expand for cotton leafworm and fall armyworm. It will demonstrate the use of the molecular tool for R&D using historical collections and data with priority on reviewing/informing RMP tactics (e.g. pupae busting, use of Magnet, and refuge crops). It will use molecular techniques to describe the regional connectedness of *Heliothis armigera*.

H: Advanced sensing for improved crop protection and field scouting in cotton (McCarthy) ★
Project timeframe: 2022-25
Management of pests that are mobile and difficult to accurately measure such as mirids, green vegetable bugs and soil pests, is challenging and can result in prophylactic insecticide use to counteract the risk created by this uncertainty. It is increasingly hard to find workforce for agronomy scouting and support, and new approaches to data management and new technologies such as artificial intelligence and machine learning have the potential to automate or augment some crop scouting activities, supporting agronomists and growers through ensuring coverage is maximised, scouting assessments are consistent and accurate and crop management decisions are informed.

This investment will address several key priorities in creating value from on farm data, and the (as-yet) significantly under realised potential of ag tech to support agronomists and growers to gather the necessary data and information to support agronomic and crop protection decision making. It will investigate technologies to automate or augment data collection on crop development, including plant growth and damage, and/or crop protection issues to support and improve crop management decision making. It may consider testing technologies available in other systems, as well as developing new technologies. In addition to development and field testing, this project should incorporate early and ongoing engagement with growers and agronomists to ensure proposed technology solution meets end user needs and is fit for purpose.

H: Improved insecticide resistance monitoring for key pests (Bird) ★
Project timeframe: 2022-23
This investment will support a cost effective program of monitoring of insecticide resistance for key cotton pests (including *Helicoverpa spp.*, mirids, aphids, mites, thrips, and other relevant emerging pests). The project will focus on insecticides relevant to a modern cotton IPM system and work with industry to ensure frequency of screening (annual/bi-annual) for pests/products is based on risk. Samples will be collected from all cotton regions, including Northern Australia. This program will also continue to explore new and novel approaches and/or technologies to improve resistance monitoring and/or pest management (e.g. spray application, adjuvants, beneficials) on insecticide resistance and IPM. This investment will support the ongoing participation in industry tech panel processes, as well as input on broader IPM activities.

H: Improving insecticide resistance monitoring for SLW (Hopkinson) ★
Project timeframe: 2022-23
This investment will support a cost effective program of monitoring of insecticide resistance for silverleaf whitefly (SLW). The project will strategically focus on insecticides relevant to a modern cotton IPM system, and work with industry to ensure frequency of screening (annual/bi-annual) is based on risk. Samples will be collected from all cotton regions, including Northern Australia. This program will also continue to explore new and novel approaches and/or technologies to improve resistance monitoring and/or pest management (e.g. spray application, adjuvants, beneficials) on insecticide resistance and IPM. This investment will support the ongoing participation in industry tech panel processes, as well as input on broader IPM activities.

CottonInfo key activities for IPM:
- Continue regional retention demonstration sites for use at field walks.
- Promote adoption of the second generation SLW app.
- Support insect resistance monitoring with regional insect collection.
- IPM and agronomy capacity building for Northern Australia.

3.8.5 Disease management

A: DAQ2002 Disease suppressive soils (Smith)
Project timeframe: 2019-22
Issue: A review of pathology highlighted that disease research should focus on a farming system that builds disease-suppressive soils. To achieve this, the review identified that elements required were tools for growers to quantify disease and soil health, advice on what to do next that considers economics and soil health and regionally-focused trials and extension.

Outcomes: The project is targeting reduced impact of disease through:
- Elements of a disease suppressive systems determined from strategic industry wide monitoring (crop, management, disease, soils, microbiology, economics).
- Ongoing access to diagnostic services (to pathogen level) for cotton diseases and disorders.
- Best practice disease management advice including protocols for Come Clean Go Clean.

R: CAS2101 Using DNA diagnostics to monitor disease suppressive cotton systems (Long)
Project timeframe: 2020-23
Issue: Current pathology uses subjective field assessments such as stem-cut surveys. These assessments may then require plating out of samples, taking 4-6 weeks depending on the disease. A multi-disease DNA test has the potential to reduce this turnaround time, increase sample throughput and inform crop planning decisions. There will be considerable technological advances in coming years, such as through hyperspectral imagery, to identify early disease symptoms. These technologies will be increasingly reliant on objective measures of disease inoculum present in field at any point in time.

Outcomes: The project will improve industry capability and responsiveness to diagnosing key diseases.

A: Improved management of Reniform nematode (Babineau)
Project timeframe: 2019-22
Issue: Reniform nematode (*Rotylenchulus reniformis*) is a relatively new threat to the cotton industry in Central Queensland and possibly further afield, should its current distribution increase. This nematode has the potential to be extremely damaging to the industry. In the United States, reniform nematode damage can cause 60% yield loss.

The reniform nematode has only been identified as causing cotton significant yield loss within the Dawson Valley, although it is unclear whether recent Emerald detections are associated with yield loss. The project is conducting pot trials to look at whether this nematode can survive in other cotton soils. It is conducting a molecular comparison across other Australian and international populations.

Outcomes: The project will use laboratory and field trials to provide the industry with management information for this nematode, including the potential for a biological control (fungi). It will help identify the most economical and practical use of this biological control while ensuring high cotton productivity.

R: DAN1703 Innovative solutions for disease (Le)
Project timeframe: 2018-21
Issue: With the exception of seed treatments, there are no fungicides or products registered for control of diseases in Australian cotton varieties. As part of an integrated disease management approach, a key focus of this project is to identify and test novel and commercial products not currently registered on cotton but with potential application for disease management in cotton production systems. While the project will review potential opportunities for all pathogens, the initial focus has been on Verticillium wilt, black root rot and Sclerotinia.

Outcomes: Growers and consultants will have access to products to reduce losses/risk from disease as part of an integrated disease management package.

H: UWS1901 Biological based products for production (Singh)
Project timeframe: 2019-22
Issue: Internationally, a number of biologically-based products are being sold for use in cotton for crop protection, including pest and disease management. Market failure can exist for the Australian cotton industry where the market is too small to attract commercial R&D.

Outcomes: This project will:
- Determine and improve the efficacy of about 100 microbial strains (obtained from Australian cotton farms) for Verticillium and Fusarium control in glasshouse and field conditions.
- Develop effective approaches to harness plant-microbiome interactions to control disease within the framework of management practices adopted by cotton farmers.
- Identify the next-generation (genomics and satellite based) biological indicators of soil heath including disease incidence and farm productivity.

R: Surveillance and management of cotton diseases in NSW (Le) ★
Timeframe: 2022-25
This project will provide significant contributions to a long-term database for the disease prevalence, distribution, and dynamics. It will also provide:
- Insights into Alternaria biology including pathogen-host interactions and diversity for an effective management of the disease and fungicide resistance.
- Insights into interactions between BRR pathogen and cotton, and soil microbial community that could help sustain BRR management.
- Insights into Fusarium population, evolution, and possible adaptation to Australia's high F-rank cultivars;
- Insights into Verticillium population and diversity, and potential management practices to minimise yield impact caused by the pathogen.
- Insights into the pathogen complex causing cotton boll rot, and management practices, including fungicide applications.

R: Tactical management and surveillance of Verticillium, Fusarium and reocurring wilt (Smith) ★

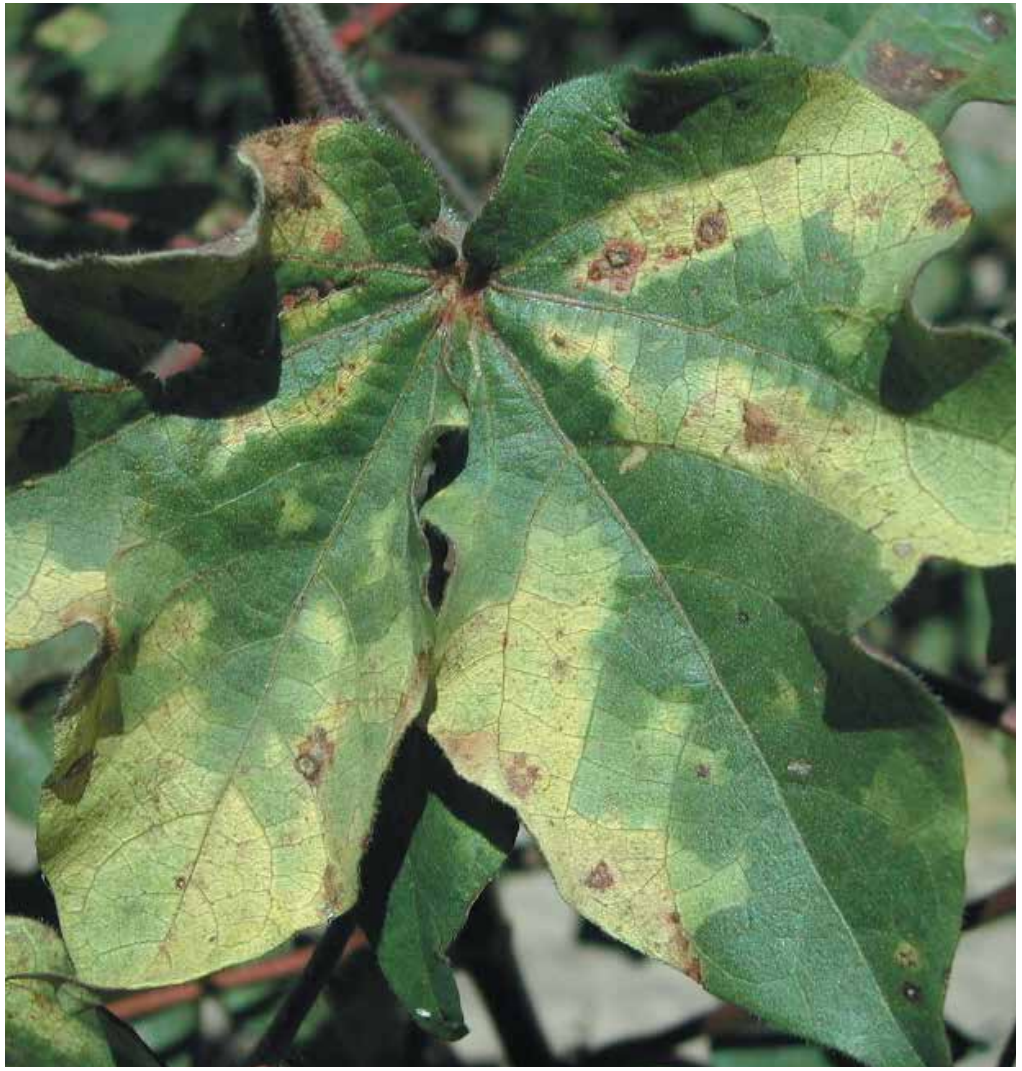
Timeframe: 2022-25

In 2020 a new cotton disease was identified in QLD, and subsequently NSW. Re-occurring wilt, a disorder associated with a Eutypella infection, has now been detected in Central QLD, St George, Border Rivers, Gwydir, and Namoi valleys. This disease behaves differently to those well known to cotton. With a significant distribution across the industry and many unknowns about this disease, understanding the impact on cotton, disease ecology and management options is a priority for CRDC and the wider cotton industry. The project seeks to develop:

- A better understanding of the causal agent of the disease including lifecycle of the pathogen, factors contributing to symptom presence and severity in cotton, and dispersal pathways.
- Potential management tactics at a field level, including cultural influences, pesticide controls, varietal influences, rotation crop influences.

CottonInfo key activities for disease management:

- Facilitate FUSCOM to share research updates and opportunities.
- Update the cotton symptoms guide.
- Macquarie Valley disease trials, monitoring heavy and light disease expression.
- REO support for disease surveys.
- Promotion of crop rotation impacts on disease.



3.8.6 Climate and economics

R: AE2101 Climate, energy and business analysis (Welsh)
Project Timeframe: 2020-23
Issue: Production risk is strongly correlated to the weather and availability of irrigation water. Understanding how these risks affect the gross margin means they can be effectively managed. This project will provide climate and energy extension support and technical leadership to the CottonInfo team and industry.

Outcomes: By clearly communicating the key variables of investment or gross margin analysis, results are extended in a way that ensures any cotton grower, in any location can consider the analysis for their own enterprise. Weather information is analysed and communications tailored to the cotton industry making it highly demanded and valued extension information.

3.5.7 Weed management

R: DAN1901 Integrated weed management (Koetz)
Project timeframe: 2018-22
Issue: The threat of herbicide resistance and the implications for weed management are a high priority for the cotton industry. Glyphosate resistance has been confirmed in 12 weed species, nine of which commonly occur in the cotton farming system. Integrating tactics across farming systems and commodities is essential to address regionally specific issues. Support is required to identify barriers to adoption across the variety of farming systems, especially with layby and residual herbicides throughout the cotton growing regions from Central Queensland to Southern NSW. Demonstration sites in at least three locations have been established and field days held to extend and promote alternatives tactics to glyphosate-only weed control such as residual and layby herbicides.

Outcomes: Involving cotton growers in this integrated weeds management project through participatory research gives growers the knowledge and understanding required to manage herbicide resistance. The evaluation of pre- and post-emergent chemistry, residual and layby herbicide applications and integrating chemical and non-chemical tactics in each region is being examined in field experiments. A series of demonstration trials are being established with test strips evaluating application timings and strategies for layby and residual herbicides. A different approach for each region may be required to account for the varying farming systems, weed species and crop rotations (plant back issues).

R: DAN2004 Improved management of weeds in cotton and grains farming systems (Charles)
Project timeframe: 2019-22
Issue: While historically the Australian cotton industry has had a strong integrated weed management system, the extensive use of herbicide tolerant (HT) cotton varieties and the spread of weeds across the landscape has seen resistant and hard-to-control weeds emerge. The need for knowledge of weeds and management tactics will need to remain contemporary, particularly as the industry continues to change, with expansion into new regions and farming systems, particularly rain grown systems and the launch of the third generation of herbicide tolerant traits, enabling over the top of the crop use of dicamba and glufosinate as well as glyphosate.

Outcomes: The industry will have clear guidelines for how to sustainably manage weeds in cotton farming systems and tactics to reduce the reliance on glyphosate.

A: GRDC2002 AWM for cropping systems weeds (Llewellyn)
Project timeframe: 2019-23
Issue: While historically the Australian cotton industry has had a strong integrated weed management system, herbicide resistance is emerging across the industry, as are difficult-to-control weeds. It is widely accepted that weed management needs to occur across the farming system. While environmental weeds are managed across the landscape by NRM bodies, this approach has not been adopted in supporting weed management in cropping systems.

Outcomes: This project will ensure weeds are managed across the cotton and grains farming systems, using science to support best practice weed management adoption.

D: Regional demonstration of integrated weed tactics across farming systems (Koetz) ★
Project timeframe: 2022-23
There are many weed tactics and technologies available in Australian cotton systems, yet there is an ongoing reliance on glyphosate and ongoing challenges with herbicide resistance and difficult to control weeds. Supporting growers to integrate different tactics and new technologies requires focus on locally relevant weed issues and understanding of the local farming system context.

This investment will support grower-led trials to reduce regional weed impacts across the entire farming system and demonstrate integrated weed management for cotton and grains systems. This will include integrating residuals and new technologies to manage emerging regional and herbicide resistant weeds, as well as stop crop injury due to herbicide carryover. Grower-led processes should inform the focus of trials.

R & A: Scientific and CottonInfo Technical lead (Charles) ★
Project timeframe: 2022-24
The project has five components:
- Undertake a risk assessment of weeds and weed management systems in cotton in Northern Australia, with base-line and ongoing surveys.
- The continuation of Eric Koetz as the CottonInfo Tech lead extension of research and technology to support adoption of best practice for integrated weed management in cotton systems.
- Review and test tactics for crop destruction and control of ratoon and volunteer cotton plants.
- Continue support of industry processes including TIMS and the herbicide tech panel with technical know-how.
- Further develop the weed control threshold model for on-farm application and will work closely with the CRDC project: Regional demonstration of weed tactics across farming systems.

CottonInfo key activities for weed management:
- Regional residual herbicide demonstrations.
- Investigate the impact of high rates under optical sprayers and impact on establishment.
- Raise awareness of weed control issues and overall spray management strategies with XtendFlex® varieties.

3.8.8 Natural resource management

A: GU2201 Environmental co-benefits of irrigation water (Zivec)
Project timeframe: 2021-24
Issue: The environmental benefit of irrigation water is currently unaccounted for in existing environmental accounting and monitoring frameworks. By gaining an improved understanding of the environmental benefits of irrigation water, state and federal governments will have a more accurate understanding of the northern Murray-Darling Basin, and the irrigation industry will be able to report to the broader community the role it is playing in building environmental resilience in times of drought and climate adaptation. This project is investigating the land and water benefits and whether on-farm water enhances the resilience of native fish, birds, and vegetation through replenishing refuge habitat in times of drought.

Outcomes: The project is increasing natural resource management research capacity within the Australian cotton industry and improving the understanding of the benefits and risks of irrigation flows on terrestrial and aquatic ecology and ecological function in the northern Murray-Darling Basin. It is informing management of irrigation flows for improved ecological outcomes, including integration of irrigation and environmental flows.

It is improving collaboration and sharing of information across the Murray Darling Basin between the cotton industry, government organisations and research groups.

A: CSP2102 Greenhouse gas baseline and mitigation for cotton (Jamali)
Project timeframe: 2021-25
Issue: Current cotton farming systems generally consist of a cycle of cotton with cereal / long fallow rotations of varying frequency. It is a low biomass system that can lead to a decline in soil carbon levels. As well as the potential to improve soil health and systems resilience through increased soil carbon levels, the carbon footprint of agricultural products is becoming an increasingly important consideration for consumers and policy makers and may become an important factor in whether cotton is selected as a raw material of choice by clothing designers. Carbon sequestration is one way farms can mitigate and off-set greenhouse gas emissions.

This project is reviewing past research and identifying and testing options for a carbon neutral cotton farm and identifying major barriers to carbon neutrality. Options will be tailored to specific farming systems, e.g. irrigated vs. dryland. It will include a focus on how to increase soil carbon levels and quantify the potential of cover crops to increase soil carbon, maximise water infiltration, and reduce the incidence of diseases and weeds.

Outcomes: This project will deliver management advice on:
- What are the main ingredients for a carbon neutral cotton farm (e.g. cover crops type).
- What are the key impediments to becoming carbon neutral x farming system (e.g. irrigated v. dryland, furrow v. pivot, regional differences).
- What are the key benefits of a carbon neutral system (e.g. compaction remediation, disease, weed control).

A: DAQ2101 A scoping study on impact of irrigation infrastructure on native fish (Hutchinson)
Project timeframe: 2020-22
Issue: Research is showing that thousands of fish per megalitre of water are being removed from river systems by irrigation pumps. The project evaluated the relative impacts of different types of cotton irrigation infrastructure on fish, trialed fish diversion technologies and assessed the environmental and economic impacts and benefits at multiple trial sites. This is leading to the development and implementation of best practice guidelines for mitigating impacts of irrigation infrastructure on fish.

Outcomes: The project identified the risk of fish entrainment from different types of infrastructure and in different river systems. It provided a cost benefit analysis of fish screens on two large pumps (up to 500ML/day) and two small pumps (up to 300ML/day).

A: Evaluating the economic and environmental ROI of modern fish screens (Boys) ★
Project timeframe: 2022-25
Diversion screens are not widely used within the Australian irrigation industry. Irrigators need to be confident that using pump diversion screens (which can be very expensive) will have a positive environmental benefit and that they won't impact pump water use and energy use efficiency, nor increase labour requirements. Additionally, it is important that irrigators have evidence that installing and maintaining pump diversion screens will not have overarching negative economic impacts for their farming business. Recently the MDBA has allocated $26 million under the Northern Basin Toolkit to incentivise screening of extraction pumps providing potential case study sites. This project will be a NSWDPI/CRDC and FRDC collaboration.

This project will:
- Demonstrate best practice screens for reducing or halting fish entrainment.
- Evaluate the environmental benefits and economic costs and benefits of fish screens (including a BCA or ROI per pump site incorporating installation, maintenance & pump efficiency).
- Provide extension and training on project outcomes.

A: Understanding carbon and biodiversity values - can these values be stacked to achieve multiple outcomes? (Smith) ★
Project timeframe: 2022-25
A number of agricultural industries are pursuing carbon neutral production supported by industry and cross-industry projects and programs which are developing GHG baselines and mitigation pathways. However, there are non-production areas on farms such as remnant native vegetation where carbon sequestration and storage occurs which are currently unaccounted for, mainly due to lack of data. Both remnant vegetation and regeneration/revegetation have value for carbon sequestration as well as other ecosystem service provision such as biodiversity conservation.
The aim of this project is to better understand the carbon sequestration and biodiversity values of native vegetation on cotton farms. This project will explore:
- What is the carbon sequestration value of common remnant native vegetation communities on cotton farms – revisit sites benchmarked 10 years ago.
- What is the avian biodiversity conservation value of common remnant native vegetation communities on cotton farms?
- How do the carbon sequestration and biodiversity conservation values interact?

CottonInfo key activities for natural resource management include:
- Continuation of the long term biodiversity management sites where positive management interventions have been implemented.
- Biodiversity kayak events in three regions.
- Fish entrainment extension.

3.8.9 Fibre quality

R: CRDC2103 Maintain and improve Australian cotton fibre quality (Van der Sluijs)
Project timeframe: 2020-23
Issue: Australian cotton is highly sought-after by international spinners and attracts a premium because of its excellent fibre characteristics and reputation for low contamination. This project has several research and extension objectives aimed at further improving this status.

Outcomes: The research objectives include:
- Establishing the impact of stripper harvesting, in terms of harvesting efficiency, and on fibre and seed quality, lint turn out, yield and return of higher yielding semi-irrigated, and immature cotton to the grower.
- Establishing the impact of alternative defoliation practices to manage regrowth for harvesting with strippers for dryland cotton production, on fibre and seed quality, lint turn out and yield.
- Establishing the impact of harvesting and ginning on seed damage and the creation of seed-coat fragment levels in cotton lint produced by southern gins.
- Continuing to establish the impact of limited water and timing on fibre quality.
- Establishing the impact of priming defoliation on yield, fibre quality and lint turn out.
- Contributing to research establishing the value of segregating cotton in the field or at the gin by quality discrimination (a collaboration with AUS and US researchers as part of the cotton value improvement initiative).

A: Defoliating cotton in a difficult environment (ICAN)
Project timeframe: 2021-22
Issue: Across all valleys (excluding CQ), sowing, defoliation commencement and picking date have all become later by 1.5-2.5 weeks. Prior to Bollgard, defoliation was commenced in March, but in the last five years defoliation has routinely commenced during mid to late April. On average, temperatures decline 4-5 °C across all regions between March and April and therefore the impact of temperature due to this delay is significant. These and other factors are contributing to increased challenges of achieving effective defoliation.

This was a one year project to explore novel approaches to defoliation and/or harvesting cotton to identify practical and innovative solutions with a reduced pesticide reliance and environmental footprint.

Outcomes: This project was focused on scoping opportunities to generate insights for a potential larger investment in one or more of the identified novel approaches.

3.8.10 Biosecurity

H: PHA2101 Review of the biosecurity plan for cotton (Plant Health Australia)

Project timeframe: 2021-24

Issue: Biosecurity planning to identify and prioritise biosecurity risks and mitigation activities is critical to ensure the industry can minimise the impact of new pests. Through representation by Cotton Australia, biosecurity planning ensures the industry complies with its legal obligations as signatories to the Emergency Plant Pest Response Deed (EPPRD). Biosecurity planning provides the industry with a framework for risk mitigation, assists in managing the impact of potential pest incursions and provides a roadmap for future investment in biosecurity. The biosecurity plan (BP) for the cotton industry was last reviewed in 2015.

Outcomes: Through this review, the industry will identify:

- Our highest risk exotic pests.
- Established pests and weeds of biosecurity significance.
- Risk mitigation activities to reduce potential biosecurity threats, including farm level activities.
- Current surveillance and diagnostic activities.

The industry biosecurity plan will be reviewed and updated through an extensive industry consultation process.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