Australian Government

Cotton Research and Development Corporation

Annual, Progress and Final Reports

Part 1 - Summary Details **REPORTS**

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: **CSP163C**

Annual Report: ☐ Due 30-September

Progress Report: ☐ Due 31-January

Final Report: ☒ Due 30-September 2005
(or within 3 months of completion of project)

Project Title: Delivering Science to Agribusiness - Novel Decision Support Tools

Project Commencement Date: 01/07/2003 **Project Completion Date:** 30/06/2005

Research Program: 1 People and Knowledge

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Plain English Summary

Project Title: Delivering Science to Agribusiness - Novel Decision support tools.

Principal Researchers: Dr M.P. Bange, Ms S. Deutscher, Mr D. Linsley, Ms L Thakur, Mr D. Richards, Mr S. Johnston and Mr. D. Larsen

Project Aims:

1. To interact with researchers, extension personnel and industry to identify critical issues where decision support tools can help growers.

2. To investigate innovative ways to process, integrate and present complex research outcomes to facilitate efficient delivery and updating of this information on different media (written, CD, WWW).

3. To provide support for researchers and to facilitate industry involvement in the development of computer decision support.

4. To maintain and support existing software packages to ensure their ongoing development, relevance and performance.

Summary:
Cotton growers are facing increasing pressure to manage resources more cost effectively and to be more accountable for the impact their decisions have on the surrounding environment. Decision support systems (DSS) have been developed to provide cotton growers with the best information available from research to assist with their management decision-making.

The aim of this project is to continue to identify critical issues where decision support tools can help growers and to develop and validate these tools. We have a range of new ideas and also requests from industry that need to be progressed over the next few years. This project will also maintain and support the existing software packages to ensure their ongoing relevance and performance. Finally, this project will also provide support for researchers, such as developing programs to help with validation of models or present data on the WWW. The approach we propose to achieve this is to combine a dedicated programmer, to ensure that the most up-to-date software design and web management is used, with an experienced cotton agronomist (Ms Sandra Deutscher), to undertake field validation of software and to understand technical issues from the industry's point of view when developing new tools.

This was the main source of funding that supports the Cotton Management Support Systems team based at Narrabri and will specifically support:

- The salary of Ms Sandra Deutscher, Experimental Scientist responsible for field validation, software evaluation and testing, as well as providing software training and support. Sandra's current and future role will also be to assist in implementing advanced computing approaches for delivery of information, such as using multi-format tools that allow rapid publication of Web, hardcopy and CD based information. Examples of these included the revised IPM guidelines and the pest and beneficial guide.
- The salary of a programmer Laxmi Thakur. The programmer is responsible for the development and maintenance of the Cotton CRC's website and new developments in handheld technology and advanced information delivery systems.
- Operating costs to fund the necessary resources for new software engineering projects, field validation, training, support, and the production and distribution of software.

This project was also jointly funded by the Australian Cotton CRC and was strongly linked to the CRDC project 'Supporting development and independent evaluation of cotton management packages'.

A range of DSS activities undertaken to assist industry in crop management were:

- NutriLOGIC Online:
- HydroLOGIC version 1;
- Commencement of CottonLOGIC redevelopment;
- Maintenance of the Cotton CRC's website;
- Implementation of the CSIRO's common modelling protocol;
- Completion of the online pest and beneficial guide.
- Assistance in completion of the revised IPM guidelines (paper based, online and on CottonPAKs);
- Release of the online Early Season Diagnosis Tool;
- Delivery of Myall Vale (ACRI) weather data online;
- Completion of a new version of the CottonLOGIC insect check cards;
- Field validation of the Early Season Diagnosis Tool and sucking pest sampling methodologies; and
- Conduct of CottonLOGIC/HydroLOGIC training workshops and provision of a decision support helpdesk.

1. Outline the background to the project.

Cotton growers are facing increasing pressure to manage resources more cost effectively and to be more accountable for the impact their decisions have on the surrounding environment. Decision support systems (DSS) have been developed to provide cotton growers with the best information available from research to assist with their management decision-making. A range of DSS are available to assist industry in crop management, they are:

- CottonLOGIC – Pest management, nitrogen nutrition management, data recording and analysis (Over 1200 copies distributed).
- CottonLOGIC for Palm OS ® – In field electronic data recording and decision tools.
- OZCOT – user friendly version used by extension personnel and APSRU's Commercial FARMSCAPE initiative. OZCOT is also extensively used in research.
- HydroLOGIC – Tactical and strategic water management tool – prototype released during 2002/2003 cotton season. Full release 2003/2004.
- WUEcalc – Field and whole farm WUE calculator used by extension personnel – ultimately to be incorporated into HydroLOGIC
- Cotton CRC's website – aims to be central repository of research based information generated by the CRC and its participating organisations.
- Cotton CRC's industry database – developed by the Cotton management support systems team and used to distribute extension material.

The aim of this project is to continue to identify critical issues where decision support tools can help growers and to develop and validate these tools. We have a range of new ideas and also requests from industry that need to be progressed over the next few years. This project will also maintain and support the existing software packages to ensure their ongoing relevance and performance. Finally, this project will also provide support for researchers, such as developing programs to help with validation of models or present data on the WWW. The approach we propose to achieve this is to combine a dedicated programmer, to ensure that the most up-to-date software design and web management is used, with an experienced cotton agronomist (Ms Sandra Deutscher), to undertake field validation of software and to understand technical issues from the industry's point of view when developing new tools.

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2. List the project objectives and the extent to which these have been achieved.

The focus of the Cotton Management Support Systems Team is to take a leading role in ensuring that good science is passed on effectively to the industry. Some outcomes of science can be delivered affectively via written documents, but increasingly there is a demand for more interactive information delivery that enables growers to tailor the information to their individual needs. There is also a demand in the rapidly changing world for up-to-date information. The aims of the project are:

1. To interact with researchers, extension personnel and industry to identify critical issues where decision support tools can help growers.
2. To investigate innovative ways to process, integrate and present complex research outcomes to facilitate efficient delivery and updating of this information on different media (written, CD, WWW).
3. To provide support for researchers and to facilitate industry involvement in the development of computer decision support.
4. To maintain and support existing software packages to ensure their ongoing development, relevance and performance.

Specific objectives and milestones are listed below:

Objectives and Milestones Year 1:

(i) Maintain and improve the functionality of the Cotton CRC's web site. Monitor acceptance of web-based information and review objectives and achievements in the light of changing technology and needs of the industry and the Cotton CRC.

(ii) Assist redevelopment of the OZCOT crop simulation model using the common modelling protocol

(iii) Complete HydroLOGIC for formal release.

(iv) Identify software and approaches to facilitate efficient information dissemination.

(v) Facilitate and assist in the update of the Pest and Beneficial Guide and IPM Guidelines, using appropriate computing technology.

(vi) Facilitate an industry advisory committee to provide direction and feedback on decision support systems.

(vii) Identify, explore and develop new opportunities for computerised decision support to assist with cotton management.

(viii) Complete redevelopment of HEAPS using the common modelling protocol.

Objectives and Milestones Year 2:

(i) Maintain and improve the functionality of the Cotton CRC's web site.

(ii) Use models from HEAPS and information from other sources to provide decision support tools for trap crops, refuges and management of Helicoverpa on them

(iii) Develop capabilities to enable simulation models to run on the web. Deliver NutriLOGIC online.

(iv) Complete an early season diagnosis tool and explore opportunities for the development of a 'DiseaseLOGIC'.

(v) Facilitate an industry advisory committee to provide direction and feedback on decision support systems.

(vi) Identify, explore and develop new opportunities for computerised decision support to assist with cotton management.

Objectives and Milestones Year 3: (Note: only funded as two year project)

(i) Maintain and improve the functionality of the Cotton CRC's web site.

(ii) Finalise incorporation of WUE calculator into HydroLOGIC.

(iii) Develop a facility on the web site to provide dates of Helicoverpa diapause induction for each region using real weather data.

(iv) Facilitate an industry advisory committee to provide direction and feedback on decision support systems.

(v) Identify, explore and develop new opportunities for computerised decision support to assist with cotton management.

(vi) Produce a final project report.

Due to reductions in project funding associated with the drought and ramp down of the Australian Cotton CRC activities designated to investigate opportunities for DiseaseLOGIC and those associated with HEAPS were not attempted. In addition to this the project was originally submitted as a three year project, but due to CRDC' s and the Cotton CRC's investment in a business plan for decision support the project was shortened to two years.

3. Detail the methodology and justify the methodology used.

This project will build on existing tools and software infrastructure, but will also exploit opportunities to develop a range of smaller focussed tools that may be delivered by CD or the Web and to further the development of some existing tools that are currently not been used effectively, such as HEAPS. Decisions about what to develop have come from feedback from our Decision Support Advisory Committee and from interactions with other researchers and members of industry organisations such as TIMS and the CRC WUE group. Some specific examples that will be explored include:

- Research advanced approaches for effective information dissemination. New systems will be trialled for the Pest and Beneficial Guide, and IPM guidelines that aim to deliver

information on all types of media without duplicating resources for production. The aim is to provide information resources on all types of media (print, web, CD) and develop mechanisms that information can be updated quickly and easily. Preliminary work suggests this is feasible.

- Enhancing CottonLOGIC to support current IPM practices. The inclusion of enhanced predator reporting capabilities, new sucking pest thresholds and linking with the OZCOT cotton crop simulation model to predict compensation are examples.
- In parallel with the above we have identified a need to exploit the capabilities of the HEAPS model, which simulates Helicoverpa population growth and dispersal over a region, to specifically support resistance management for Ingard and Bollgard II cotton and conventional insecticides. This would involve a redevelopment of HEAPS using a common modelling protocol which would enable researchers greater accessibility and allow HEAPS to be linked to other models (eg. APSIM, which simulates the growth of a range of crops). HEAPS could then be linked with models of resistance gene flow to investigate the robustness of different resistance management strategies. We envisage that this task would be undertaken by the Decision Support Scientist we are requesting in an associated project.
- Flowing from redevelopment of HEAPS we will develop a number of specific tools to enable growers to forecast, using local weather, when particular trap or refuge crops need to be planted, allowing for different varieties, to estimate the development, pupation, emergence and diapause of Helicoverpa so that trap and refuge crops can be managed effectively and to forecast the % diapause and emergence date for cotton so better pest management and pupae busting decisions can be made. This is critical for BGII which hinges on effective refuges and pupae control.
- Enhancing software information sharing capabilities through redevelopment software to export data. Part of this initiative includes establishing stronger links to other software companies and working with Area wide Management Initiatives (eg. Emerald).
  Developing new tools for the Hand-held. Work has already begun on providing GPS data entry, a whitefly sampling tool, and a whole farm status report. Opportunities include a fruiting factor calculator, plant mapping tools and disease assessment.
- Continue development of water management software initiatives. These include finalising HydroLOGIC for release and including the WUE calculator in the software.
- Enhancing NutriLOGIC for management of other nutrients in the soil.
- Improved links between CottonLOGIC and WWW services and enhance links with weather databases via the WWW.
- Explore opportunities to develop a 'DiseaseLOGIC'.
- Develop tools to assist with management of Bollgard II

There is also the opportunity to look at other sources of information and to review other needs of the industry and we envisage that the new Decision Support Scientist, requested in an associated project, would lead this process. This will ensure that we are always at the forefront in providing new tools to growers, that those tools are world-class and that the team is always moving forwards.

This project follows on from two proposals, the Cotton CRC proposal 'Developing innovative computer based technologies for effective delivery of information and cotton management decision support' and CRDC proposal 'Continued development and field evaluation of micro-computer cotton management packages'. These projects supported significant activities of the Cotton Management Support Systems team responsible for the development of cotton decision support systems team at Narrabri. Notable achievements have been the development of CottonLOGIC for the Palm OS, developing water management tools

(HydroLOGIC and WUECalc), as well as enhancing the crop simulation model OZCOT and its user friendly interface. These projects funded the salaries of Sandra Deutscher (Experimental Scientist) and Stewart Whiteside (software engineer). This new project combines these two former projects into one. This project will continue to support software development (eg. CottonLOGIC, CottonLOGIC for the Palm OS, research tools), provide training, software support, field validation as well as developing the infrastructure for the Cotton CRC's website. It therefore becomes the main project supporting the operation of the Cotton Management Support Systems Team. This new project complements the CRDC funded project 'Supporting development and independent evaluation of cotton management packages' that provides the salary for Darren Linsley the main programmer for CottonLOGIC and provides resources to evaluate the impact and nature of use of computerised decision support in the Australian Cotton Industry.
This project aims explicitly to meet objectives of Program 4 of the Cotton CRC 'Education, Transfer and Adoption of Technology' sub-program 3 'Support – Proactive information services', which are:

- Develop new DSS; and
- Enhance Web-Site facilities including access to DSS.

It is also complementary to Program 3 of the Cotton CRC (Sustainable Farming Systems), Subprogram 1 'Minimising Inputs' through the emphasis on IPM, resistance management and water use issues.

The funding requested in this the budget complements other significant funding from CSIRO, and NSW Agriculture.

4. Detail and discuss the results

This project supports part of the overall effort of the CSIRO Plant Industry Cotton Management Support Systems team based in Narrabri. Financial support is also provided by CSIRO Plant Industry and the Australian Cotton Cooperative Research Centre. A brief outline of the major results and outcomes from this project are given below under the general headings of: Decision support development and distribution; Field validation of decision support; Decision support training and support; and Decision support industry feedback.

Decision support development and distribution

The Cotton Management Support Systems Team during the course of this project completed the following tasks:

NutriLOGIC Online

NutriLOGIC recommends N fertiliser rates for cotton crops using soil or petiole nitrate N analysis. NutriLOGIC was redeveloped to be delivered online via the Cotton CRC's website.

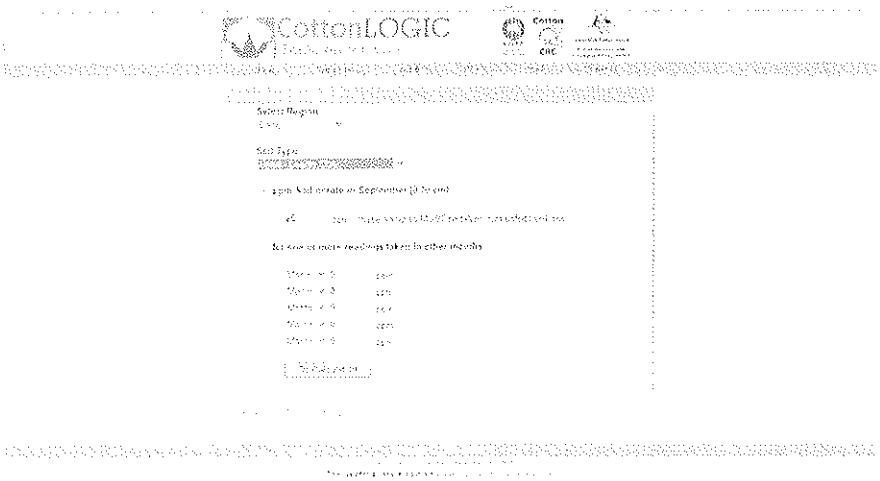


Figure: Screen shot of NutriLOGIC nitrogen DSS delivered via the Cotton CRC website.

HydroLOGIC

During the course of the project the initial version of HydroLOGIC was delivered to industry. HydroLOGIC is a cotton irrigation management tool utilising the capabilities of the OZCOT crop simulation model to assist in the effective and timely application of irrigations for furrow irrigated cotton crops. The software has the ability to evaluate the consequences of different irrigation strategies on daily crop growth, yield and water use, using a range of simple plant and soil moisture measurements.

There are four ways in which HydroLOGIC can help irrigated cotton growers make decisions regarding their production strategy:

1. Optimise their cropping area – predictions of crop growth and yield can be made using historical climate information, with a range of water allocations. The optimum irrigated cropping area can then be determined for a given water allocation.

2. Schedule the next irrigation – using HydroLOGIC to predict when a particular field will require the next irrigation, and an assessment crop growth to date.

3. Scenario analysis – using HydroLOGIC to assess the consequences of different irrigation management. This can be further broken down into two main types of 'What if' questions:

   a. Timing of irrigations – the effect of first and last irrigation dates, and the impact of stretching irrigation deficits. For example "what if I delay irrigating this field in an attempt to stretch water?" or "what if I irrigate at a lower deficit and more frequently?"

   b. Amount of water – the effect on crop growth and yield of different water availability (allocation and irrigation system efficiency). For example, 'what will crop yields be if I receive and apply an extra 2ML/ha off allocation flow?'

4. Benchmarking – calculating crop water use efficiency figures (adapted from WUE calculator developed by Drs Sunil Tennakoon and Stephen Milroy) in conjunction with actual field results, to allow comparisons between crops and seasons.

Examples of the reports generated by HydroLOGIC are contained in Appendix of the report.

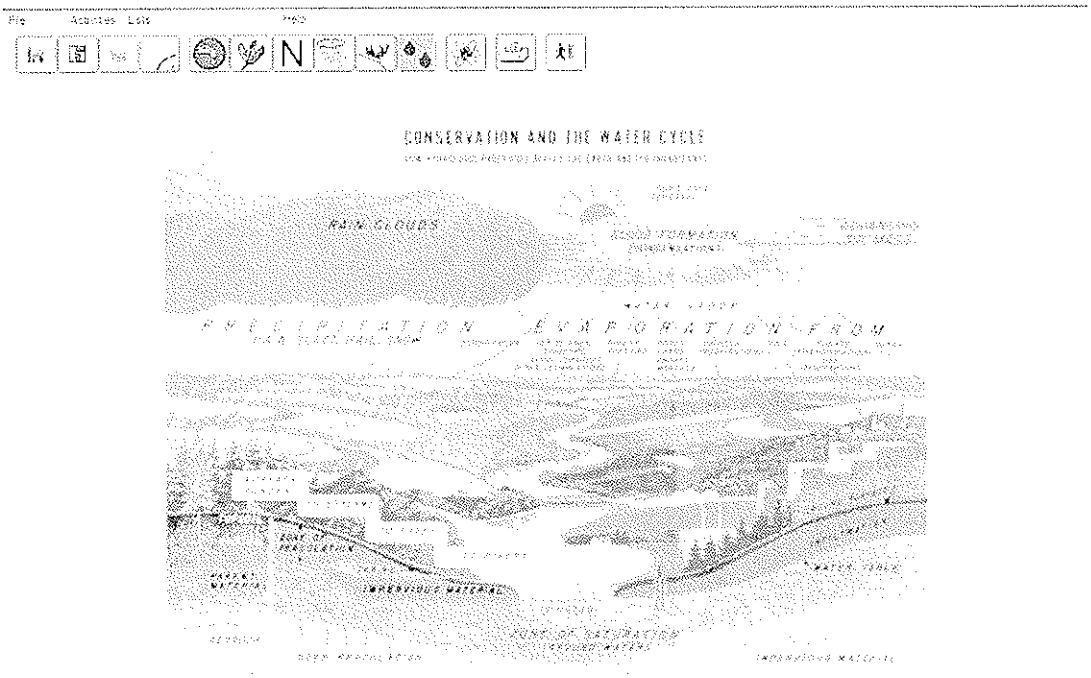


Figure: HydroLOGIC software for cotton irrigation management (opening screen).

CottonLOGIC

Significant planning into the future infrastructure of software development to maintain and improve functionality of DSS had also commenced during the course of this project. Constant input and feedback has been sort from all CottonLOGIC stakeholders (researchers, growers and industry) during the planning and design of the new CottonLOGIC software. This process has included a review of existing CottonLOGIC software, the creation of functional specification documents, technical specification documents and a software prototype. The result of this input has seen the inclusion of new ideas and also the refinement of existing concepts.

Redevelopment of EntomoLOGIC software has begun. It is anticipated that a desktop and handheld version will be made available to industry in the 2006/2007 cotton season. More details of the CottonLOGIC redevelopment are contained in the final CRDC report CSP151C 'Support development and independent evaluation of cotton management packages'.

Cotton CRC's Website

During the course of this project the Cotton Management Support Systems team have been also responsible for the technical development of the Cotton CRC's website. Over the course of this project the CRC's website has been upgraded to be a fully database driven website that enables improved functionality and management. The Cotton CRC's website has been

functioning well and usage is steadily increasing especially in the use of online decision support tools (see figure below).

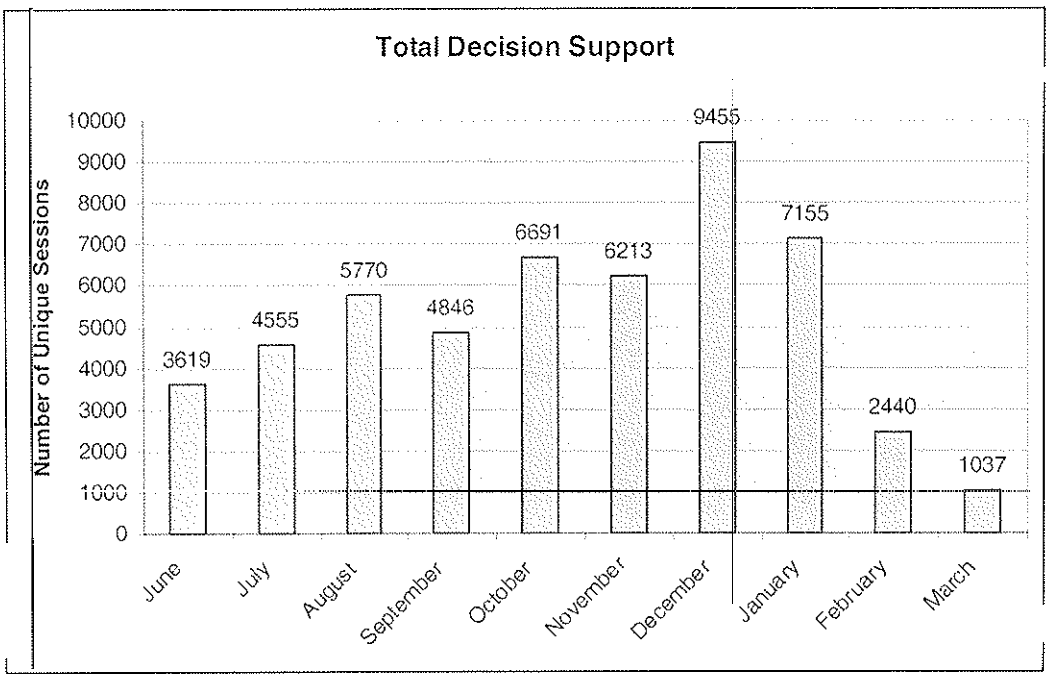


Figure: The number of web sessions recorded that detail the usage of decision tools (day degree calculator, ESD, pest and beneficial guide, NutriLOGIC) delivered on the Cotton CRC website.(June 2004 to July 2005).

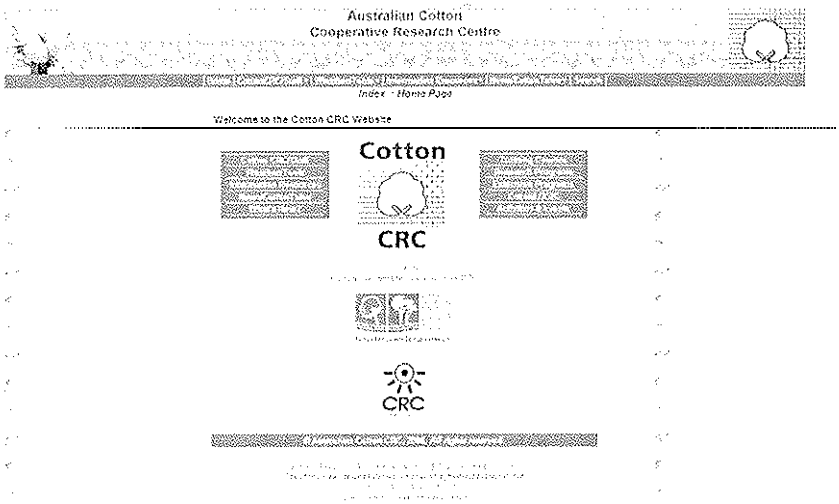


Figure: Screenshot of the Cotton CRC's homepage. The technical infrastructure and software development for the CRC's website was delivered by the CSIRO Cotton Management Support Systems team.

Common Modelling Protocol and OZCOT

The CSIRO Common Modelling Protocol (CMP) is a process by which models and decision tools are developed in a similar environment to enable sharing of information and reducing programming effort across different groups involved in the development of models and DSS.

During the course of this project members of the Cotton Management Support Systems Team collaborated with Canberra CSIRO and APSRU colleagues in implementing the CSIRO Common Modelling Protocol (CMP) as well accessing a range of tools that will assist with simulation model development.

Work on OZCOT has included the inclusion of a new Rate of Development to First Square function developed by Dr Michael Bange, work on Lint Quality simulation to a point where it is awaiting further validation, and various modifications in management routines and program logic flow to meet the requirements of the model running behind HydroLOGIC. Progress towards having a Cotton model run in a Common Modelling Protocol environment have consisted of investigations into a number of alternative approaches that could be taken to achieve the desired end point of a new fully functional and validated model. The approaches have been discussed and assessed and the preferred path has been identified. The approach that we will take will yield the greatest surety of a validated model in a workable timeframe that is not dependant upon the vagaries of proposed development paths of other modelling groups, but still allows for close integration and cooperation with other research teams.

Online Pest and Beneficial Guide

The pest and beneficial guide has been updated with new information and is currently available over the Cotton CRC's website. The information has also been transformed using the Help & Manual® software which will enable paper based and online publishing. Options on how to deliver the guide in future are now being discussed.

Figure: Screenshot of the online pest and beneficial guide delivered over the Cotton CRC website

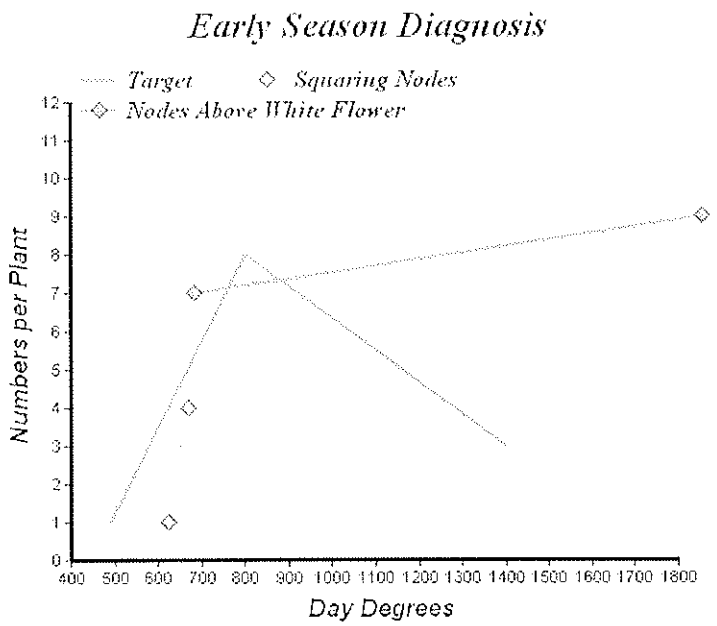
IPM Guidelines

Sandra Deutscher with the help of Lewis Wilson and Robert Mensah has re-structured the IPM guidelines using the authoring tool, Help & Manual® which enables multiplatform delivery of information (eg. WWW, hardcopy, CD etc). The IPM guidelines are now organised into a series of objectives, similar to the IPM section in the BMP manual. It has a 'how to' emphasis, explaining the tools and techniques available to achieve the objectives. Copies of the revised IPM guidelines have been printed and delivered to industry. The IPM guidelines are also available online and on the CottonPAKs CD.

Early Season Diagnosis

The early season diagnosis (ESD) tool was developed for the Cotton CRC's website to assist with the agronomic management of cotton crops. It involves a crop manger monitoring their cotton crop's development and using the ESD tool to help assess whether the crop is suffering from any stress. Early in the season the rate of fruiting node development is monitored, while later in the season the rate of nodes above white flower are monitored. Both rates are assessed against a potential rate that requires estimates of day degrees. The ESD has been linked to the SILO day degree calculator, and allows the users to enter the crop's sowing date and the dates on which the measurements were taken. The ESD then queries the patched point dataset using the SILO day degree calculator and returns the day degrees for each measurement date and then plots the results (see Figure below).

Early Season Diagnosis



Note: Date format is DD/MM/YYYY

Sowing Date 10/7/2004

SILO Station BOGGABILLA (BOONAL)

Observation Date	Day Degrees	Squaring Nodes	Observation Date	Day Degrees	Nodes Above White Flower
20/10/2004	624	1	25/10/2004	684	7
24/10/2004	670	4	24/01/2005	1854	9

Figure: The early season diagnosis web tool on the CRC website designed to assist with Bollgard II crop management.

Myall Vale Weather Data

During the course of this project a web interface to allow greater accessibility of weather and climate data for researchers at the Australian Cotton Research Institute was developed. It presents information on the current weather status as well as access to climate data records stored in a database.

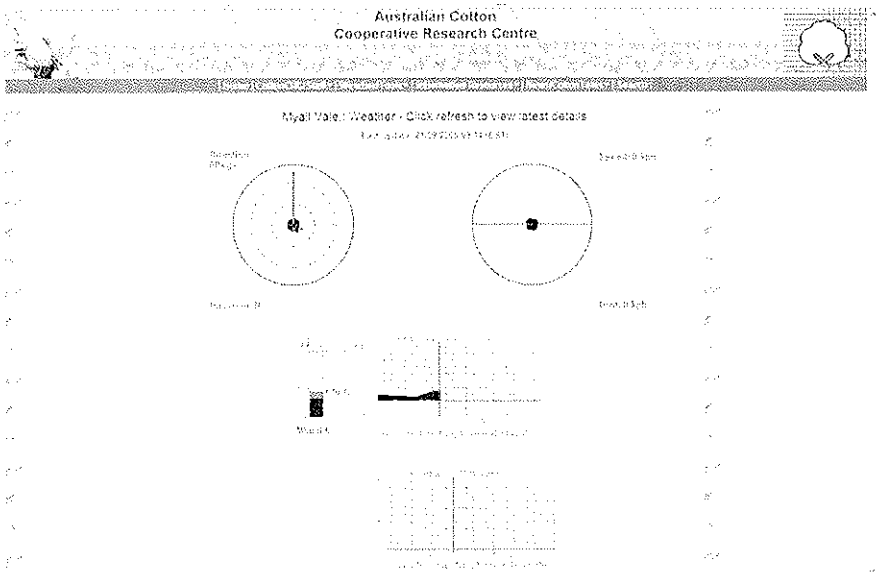


Figure: Screen shot of the Australian Cotton Research Institutes weather data delivered over the Cotton CRC's website.

CottonLOGIC Insect Check Cards

Sandra Deutscher coordinated and designed the new pest, beneficial and crop checking cards, which also support data collection for pest and beneficial densities, damage records and crop measurements used by the ESD tool. The cards were printed by CSD and a sample card was distributed to all ENTOpak users who received a new IPM Guidelines. December 2005 (Card shown below).

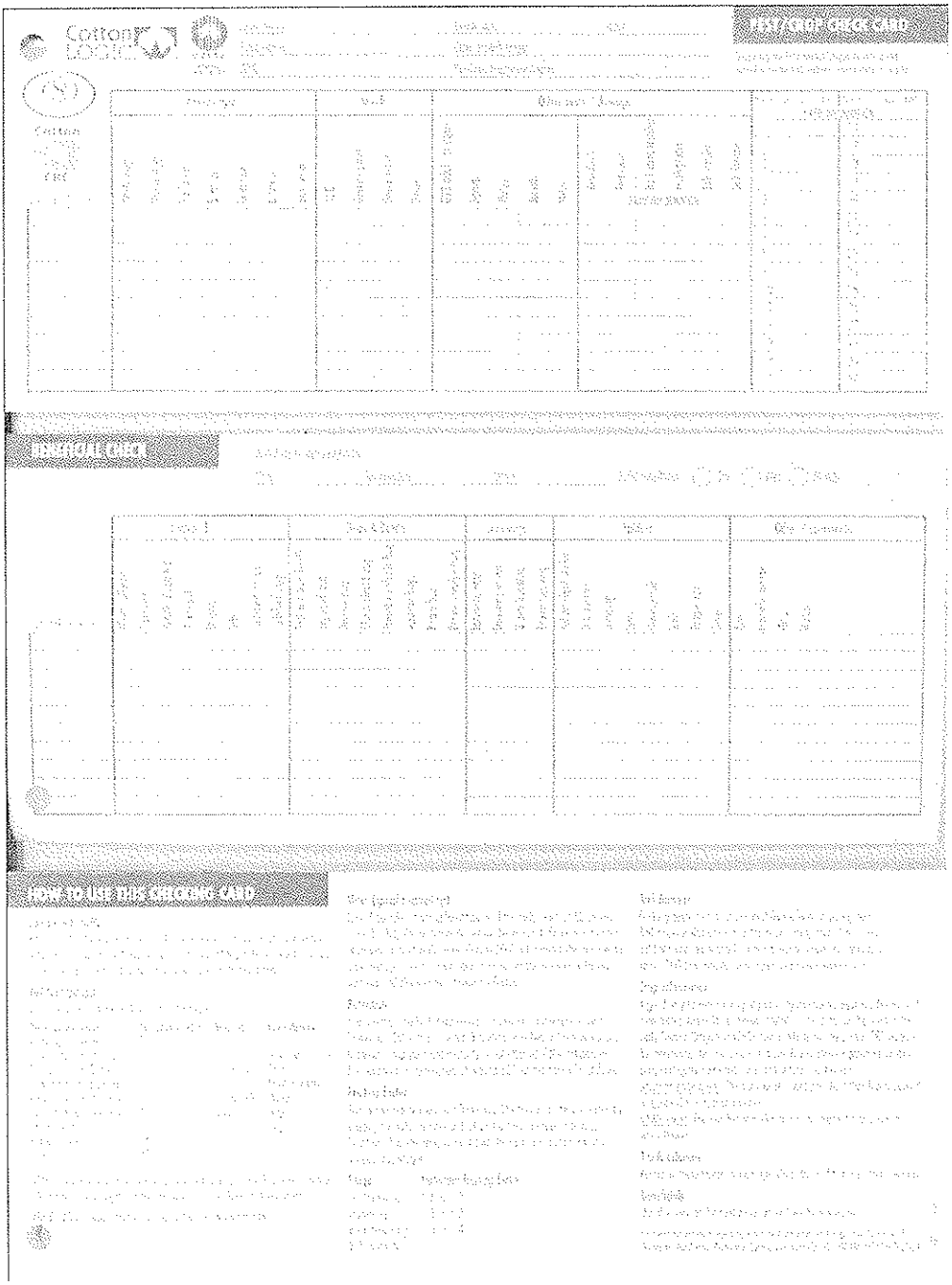


Figure: The new CottonLOGIC insect checking card supporting the ESD tool

Field validation of DSS

Validating DSS in real situations is important for developing effective and useful tools. Field validation of DSS during the course of this project consisted primarily of two components: validation of ESD Tool and testing of sampling methodologies for sucking pests.

Ms Deutscher has also completed a draft manuscript which has been reviewed by colleagues analysing the significant amount of data collected in EntomoLOGIC field validation trials conducted over many years funded in previous projects. It is envisaged that this information will be published in refereed journals and then distributed widely across the industry.

Early Season Diagnosis

The Early Season Diagnostic (ESD) tool can help cotton growers achieve optimal crop growth, maturity and yield. The web-based system graphically compares observed crop development data with a potential or target line.

During the past two seasons, the ESD tool has been tested in the field to evaluate its performance and identify opportunities for future enhancements.

Testing during the 2003/04 season consisted of monitoring established experiments which covered a number of agronomic variables including; nitrogen fertiliser rates, sowing dates, row configurations, water allocations and rotation systems. As a result of extensive field testing, various modifications occurred to the ESD tool. The NAWF line was altered, determining day degrees was automated and a squaring node identification tool was included.

During the 2004/05 season an experiment was conducted to focus on measuring the effectiveness of the ESD tool in detecting management issues early to achieve optimal yield and maturity. Results from this experiment confirmed the importance of monitoring a range of crop growth indicators which encouraged the further enhancement to the ESD tool to include a fruit development graph. The tool was then re-named the Crop Development Tool (CDT) and enhancements to the tool are being made as part of a new CRDC project titled 'Delivering science to agribusiness – Cotton management support systems'.

Sampling methodologies

Comparison of established sampling methods with the new beat sheet technique for measurement of pest and predator abundance in cotton, with summer student Carla McKinnon – 02/03

The growing popularity of the beat sheet sampling method to keep track of insect numbers in cotton was the catalyst of a study conducted in 2002/03 to determine conversion relationships by comparing current insect sampling methods. The project compared the efficiency of the beat sheet sampling method against established methods of visual checking and d-vac suction sampling. The results clearly showed that beat sheets provide superior estimates of the densities of beneficial insects and green mirids (*Creontiades dilutus*) found in cotton. However the results showed that visual checking is best for all stages of Helicoverpa, and a range of other small pests. With the exception of small wasps, d-vac sampling was the least effective method of counting insects and spiders in cotton.

An experiment to quantify the relative degree of checker bias showed that for visual sampling there were statistically significant differences between checkers in the numbers of predatory insects counted. In contrast, no significant differences between checkers were detected for beat sheet sampling.

Comparison of insect sampling methods used to estimate green mirid (Creontiades dilutus) abundance in cotton, with summer student Caragh Threlfall – 04/05 season

Accurately sampling pests and beneficial arthropods in Australian cotton crops is an essential component of integrated pest management programs. With reduced quantities of pesticides applied to Bollgard II® (transgenic) cotton, secondary pests such as the green mirid (*Creontiades dilutus*) are now becoming more common. The adult green mirid is difficult to sample due to its 'flighty nature'. Current sampling techniques include the standard visual check and more recently the beat sheet method.

A similar pest in the U.S.A., the tarnished plant bug (*Lygus lineolaris*) is accurately sampled using a sweep net. Hence the objective of this study was to examine the sweep nets ability to accurately and consistently sample the green mirid. Also to compare it to the current techniques and provide conversion factors between them.

Results from the study indicated that the sweep net method is a very fast consistent and accurate method for sampling pests and beneficials, particularly green mirid adults. Insect densities found using a sweep net can be easily converted back to industry thresholds for management.

Decision Support Training, Industry Feedback and Support

Each year of this project the Cotton Management Support Systems group conducted dedicated workshops for CottonLOGIC software in each of the major cotton growing regions.

In August 2003 nine training workshop were conducted by Sandra Deutscher and Dirk Richards across the industry with 100 participants. The locations ranged from Goondiwindi, Dalby, Emerald, Theodore and St George in Queensland, and at Moree, Hillston, Gunnedah, Bourke and Wee Waa in New South Wales. In 2004 workshops were held in similar regions with 74 attendees. Feedback showed that the workshops style and format were appropriate. Suggestions on other training in decision support were also ascertained.

Currently CottonLOGIC is been used in the Cotton CRC's cotton production course, plant protection at The University of Queensland, and the cotton production certificate through Warren TAFE.

In addition to the training the Cotton Management Support Systems has maintained a phone help desk available approximately 3 days per week through the Cotton CRC's Technology resource centre.

Constructive feedback is imperative for the development of useful decision support systems. The Cotton Management Support Systems uses the following mechanisms to assist in feedback from the industry:

- Facilitating an industry advisory committee for decision support;
- A dedicated CottonLOGIC/decision support website (see Figure below);
- CottonLOGIC training workshops;
- A dedicated phone help desk through the Cotton CRC's Technology Resource Centre;
- Attendance at industry conferences and forums;
- Evaluation using an independent consultant;
- On-farm field validation of decision support systems;
- Involvement in the Cotton CRC's extension network; and
- Formal surveys.

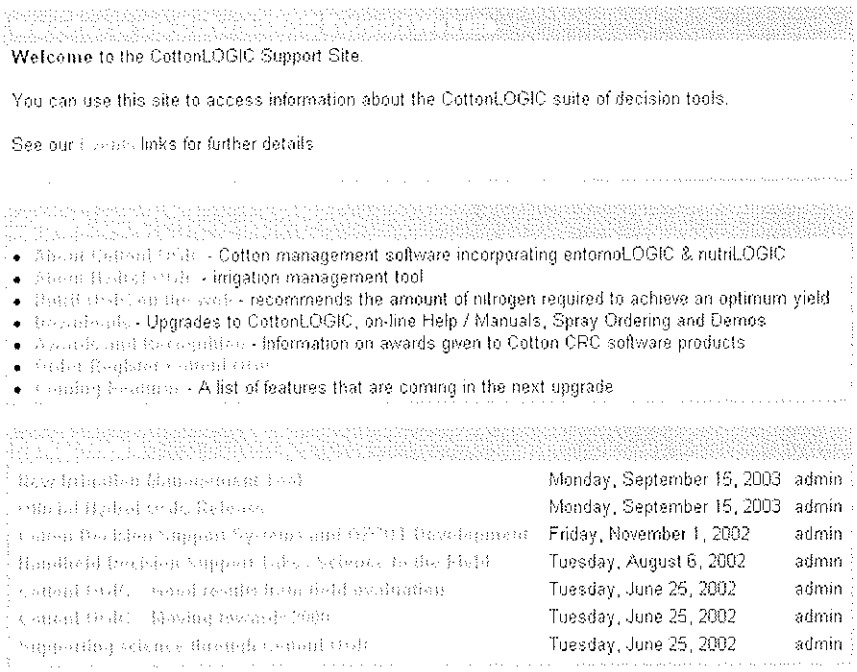


Figure: The dedicated web page designed to support CottonLOGIC users.

To instigate the specifications required for the re-development of EntomoLOGIC, a meeting was held in Goondiwindi on the 12/02/2002. This meeting aimed to bring together the Australian Cotton CRC entomologists and relevant extension staff to re-visit the old EntomoLOGIC before brainstorming ideas to incorporate the latest Integrated Pest Management (IPM) research into the new EntomoLOGIC. After this meeting the re-development specifications started to take form which included the functionality of the current system, the incorporation of IPM research and user feedback collected from past evaluations.

5. Provide a conclusion as to research outcomes compared with objectives. What are the "take home messages"?

A take home message is that this project was able to deliver a large range of world class cotton decision support tools. There is strong evidence to suggest that these tools are considered valuable to the industry. A range of DSS activities undertaken to assist industry in crop management were:

- NutriLOGIC Online;
- HydroLOGIC version 1;
- Commencement of CottonLOGIC redevelopment;
- Maintenance of the Cotton CRC's website;
- Implementation of the CSIRO's common modelling protocol;
- Completion of the online pest and beneficial guide.
- Assistance in completion of the revised IPM guidelines;
- Release of the online Early Season Diagnosis Tool;
- Delivery of Myall Vale (ACRI) weather data online;
- Completion of a new version of the CottonLOGIC insect check cards;
- Field validation of the Early Season Diagnosis Tool and sucking pest sampling methodologies; and
- Conduct of CottonLOGIC/HydroLOGIC training workshops and provision of a decision support helpdesk.

6. Detail how your research has addressed the Corporation's three Outputs - Economic, Environmental and Social?

Economic

Improved technologies to assist with optimising strategies for pest and irrigation management have the benefit to increase fibre quality and yield. Optimising inputs such as fertiliser, water and pesticides will also reduce costs and increase profitability.

Environmental

Sensible and logical decisions based on sound science and utilising information technology demonstrates a willingness to optimise use of inputs such pesticides fertiliser and water. Less pesticides and fertiliser will benefit the riverine environment. Appropriate timing of irrigation practices lessens the chance of deep drainage.

Community

Demonstration to community of the Australian cotton industry readily adopting innovative information technologies to improve regional economic and environment sustainability. The decision support software produced by the Cotton Management Support Systems Team can also be used for education and training.

7. Provide a summary of the project ensuring the following areas are addressed:

a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.)

Software was provided free to industry so no direct commercial implications at this stage are envisaged.

b) other information developed from research (eg discoveries in methodology, equipment design, etc.)

c) are changes to the Intellectual Property register required?

A summary of IP that was used and generated as part of this project is presented in the table below:

Project Participant supplying Background IP.	**Description of IP.** **All Software Tools**
CSIRO Plant Industry	CottonLOGIC Software; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes
CSIRO Plant Industry	HydroLOGIC Software; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes
CSIRO Plant Industry	EntomoLOGIC software; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes
CSIRO Plant Industry	OZCOT crop simulation model Software; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes

CSIRO Plant Industry	Early season diagnosis/day degree calculator; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes
CSIRO Plant Industry/Cotton CRC	CottonLOGIC for the Palm® handheld software; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes
CSIRO Entomology	HEAPS- Helicoverpa; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes
CSIRO Plant Industry	NutriLOGIC; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes
CSIRO Plant Industry	Cotton Scenario Generator; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes
CSIRO Plant Industry	WUEcalc; IP Situation – Copyright; Conditions of Use – Research Agreement; Freedom to Operate - Yes

8. Detail a plan for the activities or other steps that may be taken:

(a) to further develop or to exploit the project technology.

(b) for the future presentation and dissemination of the project outcomes.

Development of DSS is specifically aimed at research dissemination. CottonLOGIC and other decision support software are continually being released or upgraded via the Cotton CRC's website or distributed through the TRC. A key outcome of this project will be the provision of new tools in a number of formats (written, CD ,WWW) to meet the needs of industry. This will ensure industry-wide access. Minor releases or improvements to software are readily available through the Cotton CRC's website. Other initiatives include:

- The formal release of HydroLOGIC will occur during the life of this project.
- A redeveloped HEAPS will be made available to researchers.
- Improvements to the user-friendly OZCOT will be made available to extension personnel.
- The CRC's website will be maintained.

The Decision Support Team is a component of the Cotton Extension Team and through this group effective methods of updating industry about advances in DSS will be developed and training provided for the cotton extension team. In addition to this regular publications in the Australian Cottongrower are developed highlighting the development and use of decision support technology. Regularly members of the Cotton Management Support Systems team also present at field days and at industry conferences and forums. In order to maintain the quality of our work we also publish outcomes of our decision support development in international journals.

This project has strong links with the operation of the Technology Resource Centre of the Cotton CRC and delivery of research outcomes from both CRDC and Cotton CRC funded projects.

(c) for future research.

A project titled 'Delivering science to agribusiness – Cotton management support systems' has been supported by the CRDC and Cotton CRC that combines this project and the project 'Supporting the development and independent evaluation of cotton management' also

supported by the CRDC, and one by the Cotton CRC. The new project will become the principle project that supports the cotton industry's investment in decision support development.

The new project will build on existing tools and software and develop new infrastructure in the case of CottonLOGIC, but will also exploit opportunities to develop a range of smaller focussed tools that may be delivered by CD or the Web and to further the development of some existing tools that are currently not being used effectively, such as HEAPS. Some specific examples of other activities and opportunities that will be undertaken include:

- Undergo routine maintenance of CottonLOGIC software infrastructure to meet future needs of all sectors of the industry.
- Scope opportunities to allow CottonLOGIC to support fibre to fabric, BMP and CCA initiatives.
- Redevelop EntomoLOGIC to meet current and future IPM systems.
- Upgrade HydroLOGIC and the handheld version of CottonLOGIC.
- Research advanced approaches for effective information dissemination and collection eg. wireless technologies (eg. 1XRTT technology by Telstra).
- Exploit the capabilities of the science based modelling capabilities (eg. OZCOT and HEAPS)
- Enhance NutriLOGIC for management of other nutrients in the soil.
- Explore opportunities to develop a 'DiseaseLOGIC'.
- Develop tools to optimise yield and quality of Bollgard II and future transgenics.
- Develop other online decision tools such as the early season diagnosis tool.
- Enhance and maintain Cotton CRC website infrastructure
- Facilitate an industry advisory committee
- Conduct independent evaluation of the impact of computerised decision support.
- Provide software support and dedicated training.

9. List the publications arising from the research project and/or a publication plan. (NB: Where possible, please provide a copy of any publication/s)

Refereed Journals:

Bange, M.P., Deutscher, S.A., Larsen, D., Linsley,D., and Whiteside, S. (2004). Handheld decision support system facilitates improved insect pest management in Australian cotton systems. Computers and Electronics in Agriculture. 43(2): 131-147.

Conference papers:

Christiansen, I., Callan, V., Roth, G., Bange, M., Coutts, J. (2004). Knowledge and learning in the Australian cotton industry. Proceedings International Crop Science Congress. Brisbane.

Deutscher, S.D., and Bange, M.P. (2003). Advancements in computerised decision support for Australian cotton systems. In Proc. 3nd World Cotton Conf. Capetown, South Africa.

Deutscher, S., Johnston, S., and Thakur, L. 2004. The ESD tool helps you stay in control of your Bollgard® II crop. In Proceedings of the 12th Australian Cotton Conference pp. 223 – 227.

Moore, A.D., Angus, J.F., Bange, M.P., Crispin, C.J., Donnelly, J.R., Freer, M., Herrmann, N.I., Ottey, H.E., Richards, Q.D., Salmon, L., Stapper, M. and Suladze, A. (2004). Decision support tools for Australian farmers. Proceedings International Crop Science Congress. Brisbane.

Kelly, D., McLennan, A., Pyke, B., Hickman, M., Deutscher, S. and Kauter, G. 2004. Industry perceptions on management issues associated with Bollgard® II. In Proceedings of the 12th Australian Cotton Conference pp. 215 – 222.

Reviews and Book Chapters:

Deutscher, S., Wilson, L. and Mensah, R. 2004. Integrated Pest Management Guidelines for Cotton Production Systems in Australia. The Australian Cotton Cooperative Research Centre. Paragon Printers Australasian.

Conferences Presentations:

Bange, M.P. (2003). Building and Maintaining the Bridge: From Research to Technology Transfer. In Proc. Integrated Biological Systems Conference. 14-16 April, San Antonio, Texas, USA. Biological Systems Simulation Group. pp. 28-29.

Bange M.P. , 2004, Invited speaker at Florida University, University of Arkansas, Texas A&M University (Lubbock, Uvalde, College Station, Sinton, Beaumont) on 'Advancements in Decision Support in the Australian Cotton Industry' and in Toowoomba on 'Opportunities for Texas Farming Systems'.

Deutscher, S.D., and Bange, M.P. (2003). Advancements in computerised decision support for Australian cotton systems. In Proc. 3nd World Cotton Conf. Capetown, South Africa.

Seminars, Workshops & Trade Shows:

Sandra Deutscher gave a presentation on the comparison of the beat sheet technique with established methods for sampling pest and predator abundance in cotton. Annual grower/consultant update, Goondiwindi, June 2003.

Sandra Deutscher gave a presentation on comparison of the beat sheet technique with established methods for sampling pest and predator abundance in cotton. Annual grower/consultant update, Mungindi, July 2003.

Richards, QD and Deutscher SD, 2004, Cotton, science and technology, seminar to students from Calrossy High School with Sandra Deutscher, at ACRI, 3rd May 2004, Narrabri.

Deutscher, S. A., facilitated a number a small workshops aimed to educate the industry about monitoring Bollgard II crops, this included the use of the ESD tool. During the August 2004 Australian Cotton Conference.

Deutscher, S. A., assisted in manning the Cotton CRC stand at 12th Australian Cotton Conference, 10-12th August 2004, Broadbeach.

Deutscher, S. A., demonstrated CottonLOGIC for the Palm to a group of Calrossi year 11 students, and also attended a high school careers day in Wee Waa to promote careers in cotton research. May 2004.

Deutscher, S. A., as a member of the extension insect focus team, assisted at the Moree Trade show CRC extension team stand and coordinated the parasitic wasp display. May 2004.

Deutscher, S. A., presented - Comparison of the beat sheet technique with established methods for sampling pest and predator abundance in cotton. CSD/CSIRO seminar, RSL Narrabri July 2004.

Deutscher, S. A., presented – Using the web based Early Season Diagnostic tool to help manage Bollgard® II cotton. CSD/CSIRO seminar, RSL Narrabri July 2004.

Deutscher, S. A., presented - results from the 2002/03 CRC summer student project which evaluated the beat sheet insect sampling method at a green mirid research review. CRDC, Narrabri, July 04.

Deutscher, S. A., presented information about the ESD validation trials for the Farming Systems Forum, held at the ACRI, December 2004.

Deutscher, S. A., presented information about the ESD tool and secondary pest sampling at a Bollgard® II field walk in Hillston. December 2004.

Deutscher, S. A., presented results from the 04/05 summer student project at a breakfast meeting at Mallaley to discuss late season Bollgard® II pests and to meet up with Deputy PM John Anderson who officially launched the IPM guidelines. February 2005.

Deutscher, S. A., in collaboration with Trudy Staines, coordinated and managed the secondary pest display at the Biotechnology open day, Narrabri, 8th April 2005.

Grower Magazines and Articles:

Deustcher, S.D., and Bange, M.P. (2003). Cotton decision support – What does the future hold? The Australian Cottongrower. 24(4). pp. 6-8.

Deustcher, S.D., Bange, M.P., Larsen, D. and Richards, D. (2004). Delivering science to agribusiness: Australia's cotton research on the net. The Australian Cottongrower. 25(3). pp. 50-52.

Deutscher, S. A., Dillon, M., McKinnon, C., Mansfield, S., Staines, T., and Louise Lawrence. (2003) Giving insects a good beating. The Australian Cottongrower. June/July issue.

Richards, D.Q., Bange, M.P., Linsley, D. and Johnston, S. (2004). Challenging weather conditions during the 2003-4 cotton season. The Australian Cottongrower 25(3) pp.54-56.

Richards, QD. 2005. HydroLOGIC for irrigation decisions, Lower Namoi 2005 Field day book, January 2005.

Richards QD and Deutscher made contributions were made to the CSD 'An Australian guide to Bollgard II management' publication in October 2004.

Threlfall, C. and Deutscher, S. 2004. Comparison of sampling techniques in cotton, Lower Namoi Field 2005 field day book, 32-33 January 2005.

Deutscher, S. A., coordinated and designed the new pest, beneficial and crop checking cards, which support data collection for the ESD tool. The cards were printed by CSD and a sample card was distributed to all ENTOpak users who received a new IPM Guidelines. December 2005.

Software Manuals:

Richards, D., Bange, M.P., and Johnston, S.B. (2003) HydroLOGIC Irrigation water management and risk analysis software User Manual V1.01, CSIRO Plant Industry and Australian Cotton CRC, September 2003.

Media interviews:

Deutscher, S. A., interviewed regarding the use of the ESD tool for a Bollgard II management video that was produced for the Cotton Seed Distributors/CSIRO road show. July 2004.

Deutscher, S. A., presented how to use the ESD tool for the Cotton Seed Distributors web on a Wednesday. December 2004.

Deutscher, S. A., spoke on a Moree based radio station about managing Bollgard® II crops using the ESD tool. November 2004.

Deutscher, S. A., spoke on a Moree based radio station about green mirid sampling. May 2005.

10. Have you developed any online resources and what is the website address?

Online decision support tools developed by the Cotton Management Support Systems team delivered via the web include:

Name	Purpose	Address
CottonLOGIC Support	Provision of support, upgrades and feedback	www.cotton.crc.org.au/CottonLOGIC
SILO day degree calculator	Calculates day degrees and provides historical analysis	http://www.cotton.crc.org.au/Tools/Agronomy /SILODayDegCalc.htm
Early season diagnosis tool	Crop monitoring tool based on SILO day degree calculator	www.cotton.crc.org.au/esd
Pest and Beneficial Guides	Online resource for cotton insects	http://www.cotton.crc.org.au/insects.htm

11. **Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. Where possible include a statement of the costs and potential benefits to the Australian cotton industry or the Australian community.**

This project explicitly addresses the CRDC outputs: Sustainability by empowering people with technologies that enhance the latest and best knowledge generated by latest cotton research. Technology can assist with complex decisions that can integrate knowledge that optimise production and inputs that are sensible, profitable, and have the lowest impact on the surrounding environment. CottonLOGIC and many of the software generated by the Cotton Management Support systems team are already industry standards in record keeping and pest management and aspects of irrigation management, and thus its use is recommended in the many components of Best Management Practice guidelines.

Appendices

Examples of HydroLOGIC reports

Multiple Scenario Comparison - End Of Season Status

Farm: Cotton Research Station

Field: Paddock 5

Crop: Roundup Ready

Variety: [illegible] Sown: 01/10/2002

Scenario	Run Date	Total Irrig	Pre-run Pumped (ML)	Post-run Pumped (ML)	Water Pumped (ML)	Water Left (ML)	Total Rain (mm)	60% Open	Total Bolls (/m2)	Yield (Bales/ha) Avg	Yield (Bales/ha) 50%	Yield (Bales/ha) 70%	Irrigation Water Use Index (Bales/ML/ha) Avg	Irrigation Water Use Index (Bales/ML/ha) 50%	Irrigation Water Use Index (Bales/ML/ha) 70%
Deficit to optimise yield 100	10 Jan	3	1.4	1.3	3.4	0.3	394	15 Mar	108	6.4	6.1	6.9	1.9	1.5	1.9
Deficit to optimise yield 120	10 Jan	2	1.4	1.6	3.0	0.4	395	12 Mar	105	6.3	5.7	6.9	2.1	2.0	2.1
Deficit to optimise yield 80	10 Jan	3	1.4	1.3	3.4	0.3	397	16 Mar	104	6.3	5.9	6.5	1.9	1.9	1.9
Deficit to optimise yield 90	10 Jan	3	1.4	1.3	3.4	0.3	392	16 Mar	107	6.4	6.1	7.3	1.9	2.0	1.9
4 Scenarios				1.3	3.3	0.3			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Note: Percentiles divide a dataset into 100 equal parts and provide information on the range of values predicted. 50: the 50th Yield percentile is the smallest Yield that is greater than or equal to 50% of the Yields predicted.

Summary Table

Farm: Cotton Research Station
Field: Paddock 1
Crop: Bollgard II(Variety: SICKRA Sown: 01/10/2002)

Scenario: Efficiency 100 — Single Irrigation Deficit

Run date: 02/10/2002
Pre-irrigation/water up / /
Last irrigation 20% open bolls
Deficit to irrigate 90mm
Irrigation efficiency 100 %
Use future weather from NARRABRI WEST POST OFFICE
Use rainfall from Met-station
Assume rainfall after run date: Yes

Estimated water remaining at run date
River: 6.0 ML/ha
Bore: 0.0 ML/ha
Storage: 2.0 ML/ha
8.0

Status @ 02/10/2002	
Total irrigations	0
Water pumped (ML/ha)	0.0
Water left (ML/ha)	8.0
Squares (/m2)	0
Green bolls (/m2)	0
Open bolls (/m2)	0
% open bolls	0

Status @ end of season	Avg	30 %	70 %
Total irrigations	4	3	5
Estimated yield (Bales/ha)	4.37	4.17	4.70
Water pumped (ML/ha)	3.31	3.26	3.36
Water use efficiency (kg lint/mm)	1.42	1.32	1.55
60% open (Maturity)	29.03.2003	19.03.2003	05.04.2003
Open bolls (/m2)	82.26	76.12	90.89

Irrigation Summary

Date	Deficit at irrigation (mm)	Water pumped (ML/ha)
06.10.2002	53	0.53
04.01.2003	92	0.92
23.01.2003	93	0.93
06.02.2003	93	0.93

Next Irrigation...

Average			30 %			70 %		
06.10.2002	53 mm	0.53 ML/ha	02.10.2002	51 mm	0.51 ML/ha	02.10.2002	53 mm	0.53 ML/ha

Note: Percentiles divide a dataset into 100 equal parts and provide information on the range of values predicted. EG: the 30th Yield percentile is the smallest Yield that is greater than or equal to 30% of the Yields predicted.