

# COTTON RESEARCH AND DEVELOPMENT CORPORATION

## FINAL REPORT 1990/91

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**PROJECT CODE :** CSP8C  
**ORGANISATION :** CSIRO Division of Plant Industry  
**PROJECT TITLE :** Development of micro-computer cotton management packages

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This project was initiated under the name "CS66L - SIRATAC Plus configuration and testing". However, the Siratac Plus project proved a failure and all development was abandoned in 1990. These developments were reported in progress reports for Project CS66L in 1990/91. At that time it was decided that the future for computer based pest management for the cotton industry was in standalone microcomputer packages. Consequently staff employed in design of the water balance model (A.T. Wells) and testing of SIRATAC Plus (S. Griffin) were re-deployed to the construction and testing of hydroLOGIC; a 3rd generation decision support system (DSS) for irrigation management, further development of the cotton model and to the development of entomoLOGIC, an expert system for pest management. This report covers these developments in detail.

### **Cotton model rewriting and development of hydroLOGIC.**

Much work with components of the cotton model had been undertaken as part of SIRATAC Plus and was continued under this project. The existing water-balance and leaf growth sub-models were re-written, in parallel with similar work on other parts of the model by Steve Marsden and people from the CSIRO Division of Information Technology. The purpose of re-writing was to make a fresh start on the models so that the code could be more easily maintained and understood. This new "clean" code allowed fast development of the prototype irrigation decision support program "Hydrologic" originally developed on the VAX Mini-computer. It also greatly eased the work involved in porting the models to micro-computers.

The rewriting and initial development of Hydrologic required extensive testing and verification of the models which was carried out in conjunction with Steve Marsden. Additionally, when the code was converted from Fortran to Pascal so that the models would operate smoothly in the micro-computer environment, further lengthy testing was required.

### **Hydrologic programming on micro-computers.**

“Ozcot” is the cotton crop model developed largely by Brian Hearn over a period of approximately 10 years. It is linked to a water-balance and simple nitrogen sub-model. “Hydrologic” is, in essence, the reimplementation of “Ozcot” on a micro-computer. It is an attempt to deliver research findings to the cotton industry by packaging the integrated understanding of cotton growth and development into computer simulation models that cotton growers, consultants, students and any other interested people can explore. It is not so much an attempt to solve a particular problem but to provide the industry with a tool for dealing with a range of irrigation/agronomy problems which may be different for each farm.

From the start versions of “Hydrologic” were developed for both IBM compatible (Steve Marsden) and Macintosh computers (Tony Wells) to make it available to the whole industry. The two systems were very different to work with and the job of building a user interface on each platform used quite independent methods. However, only small changes in the model code were required for it to run on either platform. This model portability was very convenient not only as it saved time initially but allowed changes to the model to be quickly implemented on both computer systems.

After experimenting with various Macintosh programming tools a system called MacApp was chosen for implementing the Macintosh user interface. MacApp is a product developed by Apple which uses a new computer programming method called object oriented programming. MacApp is used to build robust interfaces which conform to the standard Macintosh interface style while providing complete flexibility to design unique features required by your particular application.

The IBM version is now commercially available through an agreement between CSIRO and Neutron Probe Services. Marketing and promotion of the package, for which NPS are responsible, commenced in mid 1991. However, the Macintosh version, although developed to a high level, remains unfinished and still requires considerable work to bring it to full commercial standard. The delay of the Macintosh version is the result of both the greater complexity involved in Macintosh programming and my not having sufficient time available to complete the work.

### **Cotton model enhancements.**

During work on "Hydrologic" various limitations of the underlying models became apparent. These were identified largely because of the ability of "Hydrologic" to produce graphs of model behaviour and so display the dynamic interaction of the various sub-models clearly. This graphical insight into the models was not as readily available before and some problems were not noticed in the normal tabular data output. These limitations had little impact when the model was used for standard types of applications such as modelling yield response to irrigation on typical cotton growing soils. However, when the model was put to more demanding uses such as modelling the effect of soil compaction layers or estimating optimal varietal characteristics it did not perform well. There was also a desire to investigate nitrogen questions with the model but the simple nitrogen sub-model that it used was not detailed enough.

In response to these limitations of the model, programming of the Macintosh interface was deferred while these problems were addressed (Tony Wells in collaboration with Doug Godwin and Brian Hearn). This work is currently being continued in a new project entitled "Development of the Ozcot cotton crop simulation model".

The key improvements to the model were identified as: 1. the incorporation of a complete carbon balance for the cotton crop; 2. a more realistic water-balance model; 3. more realistic soil and plant nitrogen sub-models and; 4. the ability to model the behaviour of the new cotton varieties.

"Ozcot" is being upgraded along the lines of the CERES style of crop simulation models extensively developed by Doug Godwin over several years. The soil-water balance and soil nitrogen sub-models from the CERES models are being used in modified form. The format for input and output of data to and from the model will also be borrowed from CERES. This will allow the use of the graphics packages that CERES uses. These will be very useful for refining and calibrating the models as our experience with "Hydrologic" graphics has shown us.

A field trial was carried out in the 1990-91 cotton season to measure the behaviour of the new CSIRO commercial cotton varieties in terms of the cotton model parameters. These parameters included leaf area development rate, dry-matter accumulation, squaring rate, and thermal time requirements to reach various development stages.

Preliminary work on incorporating the CERES input/output formats was carried out as well as some modification of the CERES water-balance to better model water movement in cracking clay soils. Measurement of rainfall intensity and runoff from a cotton field were

also made to assist in calibrating the water-balance. The equipment for these measurements was purchased with funding from the project "CSP20C Measurement of complete water balance of a cotton field".

These enhancements to the cotton crop model will allow far greater power in decision support packages that are based on them. The model will be able to be used for investigating new problems involving factors such as nitrogen uptake, tillage practices, the latest cotton varieties and different soil bed formations. As well, the more typical applications of the model should receive more reliable results particularly in problem soils and in marginal cotton growing areas.

### **Development of entomoLOGIC: a pest management system for cotton**

entomoLOGIC is an prototype expert system for cotton pest management which was developed after the abandonment of the Siratac Plus project. It's purpose is to assist in making pest management decisions and to provide a simple tool for recording insect counts and sprays. The current version of entomoLOGIC is a HyperCard™ application for the Apple Macintosh™ computer.

entomoLOGIC was derived from the SIRATAC pest management model, but is considerably simplified. It uses similar procedures for insect pest sampling and the same rule base for spray decisions, but currently does not use the SIRATAC crop and *Heliothis* models. Data are checked when entered to ensure that they are consistent and within reasonable bounds. Presence / absence insect samples are converted to numbers per metre for comparison with standard action thresholds. Default thresholds are suggested based on the best current practice, but these can be over-ridden with user entered thresholds if desired. It suggests whether the pest situation warrants chemical control. If necessary, it suggests which pesticides to use and why. Some of the data can be graphed within the program. Alternatively, the data can be copied into a spreadsheet or graphics package for further analysis.

Work commenced on the entomoLOGIC project May/June 1990. After initial work on interface design features rapid development was achieved using HyperCard. The reasons for this were that we felt that the graphical user interface of the Macintosh was needed for product acceptance. The crude line-by-line interface of Siratac was one of the major technical defects noted by users. HyperCard was chosen as the language as it allows non-professional programmers to develop a high quality interface quickly. It's language, Hypertalk, is comparatively easy to understand and use. Also expert systems which use

HyperCard as a front end were readily available. Further, the card system of HyperCard is congruent with the use of sampling cards for insect pest management which was promoted by Siratac and was familiar to growers.

Since that time the overall design and structure of the program has been completed. The computer code is almost complete. All work completed so far has been debugged and tested so that it is functioning as intended.

A comprehensive user manual has also been completed.

### **Field trials with entomoLOGIC**

Development of entomoLOGIC proceeded so quickly that a working prototype was available for field testing during the 1990/91 cotton season by 5 growers in the Macquarie, Namoi and McIntyre Valleys (a total of 1663 ha). The field testing consisted of the growers selecting several management units on which to run Siratac and entomoLOGIC simultaneously. Each grower was visited approximately fortnightly throughout the season to encourage use of the program and to address operational difficulties as they arose. Changes to the interface and program structure could then be suggested. In most cases spray decisions and chemical selection between Siratac and entomoLOGIC were similar. However, there were vast differences between the number of spray applications and the recommendations of both Siratac and entomoLOGIC (Table 1). In one instance, both Siratac and entomoLOGIC did not recommend any sprays throughout the season whilst eight sprays were applied. In another, Siratac recommended no sprays, entomoLOGIC two whilst fifteen were actually applied. These anomalous results arose because growers consistently pre-empted the default thresholds. This indicated that neither Siratac nor entomoLOGIC were recommending sprays as often as growers felt comfortable with and suggests that further work is needed to validate entomoLOGIC recommendations against opinions of other expert opinion within the industry.

Users of entomoLOGIC were generally happy with the program. Growers were impressed with the graphical interface, ease of use with data entry and editing facilities, which they considered an improvement over Siratac. They seemed more interested in the report writing and record keeping capabilities than in the pest management recommendations (refer Table 1). The growers selected for the field testing were experienced in making pest management decisions. However, the spray recommendations were seen to be of value in training new staff and also provided a standard for insecticide use on larger farms that employed several and/or changing staff.

Table 1: Comparison of the number of sprays recommended by Siratac and entomoLOGIC against the number actually applied.

		Siratac	entomoLOGIC	Actual
<b>Total</b>	Farm 1 - 424ha	0	0	8
	Farm 2 - 253ha	4	3	9
	Farm 3 - 229ha	0	2	15
	Farm 4 - 625ha	9	9	13
	Farm 5 - 132ha	3	1	6
	<b>Average</b>	3.20	3.00	10.20
	<b>St.Dev</b>	3.70	3.54	3.70
<b>Range</b>	0 - 9	0 - 9	6 - 15	
<b>Stage 1</b>	Farm 1	0	0	4
	Farm 2	1	0	5
	Farm 3	0	2	11
	Farm 4	3	3	7
	Farm 5	1	1	3
	<b>Average</b>	1.00	1.20	6.00
	<b>St.Dev</b>	1.22	1.30	3.16
<b>Range</b>	0 - 3	0 - 3	3 - 11	
<b>Stage 2</b>	Farm 1	0	0	4
	Farm 2	3	3	3
	Farm 3	0	0	3
	Farm 4	3	3	4
	Farm 5	1	0	2
	<b>Average</b>	1.40	1.20	3.20
	<b>St.Dev</b>	1.52	1.64	0.84
<b>Range</b>	0 - 3	0 - 3	2 - 4	
<b>Stage 3</b>	Farm 1	0	0	0
	Farm 2	0	0	1
	Farm 3	0	0	1
	Farm 4	3	3	2
	Farm 5	1	0	1
	<b>Average</b>	0.80	0.60	1.00
	<b>St.Dev</b>	1.30	1.34	0.71
<b>Range</b>	0 - 3	0 - 3	0 - 2	

Problems with the prototype as a result of the field testing were:

- (1) Time taken to run the expert system
- (2) Data wasn't separate from main program so that changes could not be made to the program throughout the season
- (3) No explanation of spray preferences
- (4) Growers use cost as a basis for chemical selection
- (5) Lack of information about pest and crop development
- (6) Only available on the Macintosh and not the IBM

The time taken to run the entomoLOGIC expert system for one management unit on a Macintosh SE (the machine most growers would have) was three minutes, compared with about two minutes for Siratac on a VAX 11/750. It is slow because Hypertalk is an interpreted language. Use of the expert system shell also slowed execution. Execution of the expert system consultation has now been speeded by placing restrictions on calls to the expert system shell (Table 2). Further developments to improve run time are possible for the future.

Table 2: Comparison of time taken to run the entomoLOGIC expert system by placing restrictions on calls to the expert system shell on a Macintosh SE/30 and Macintosh SE.

		Prototype Restricted		% Increase in speed
SE/30	No pests over	49 secs	12 secs	75
	Heliothis over	49 secs	29 secs	40
	Heliothis+mites over	49 secs	30 secs	38
	Heliothis+mites+aphids over	49 secs	31 secs	36
SE	No pests over	3 mins	45 secs	75
	Heliothis over	3 mins	1 min 38 secs	45
	Heliothis+mites over	3 mins	1 min 46 secs	41
	Heliothis+mites+aphids over	3 mins	1 min 54 secs	36

During field testing a major structural problem with entomoLOGIC was highlighted. By using HyperCard, the data was contained within the program, making it difficult to provide updates or modify the version used by growers without losing their data. To cope with this a data import/ export function was developed and is now complete.

Since the rule base of entomoLOGIC was derived from Siratac, both use a rating system to justify why a particular chemical should be used in preference to another. Growers weren't happy with this ratings system as they didn't always agree with the types of chemicals recommended and there was no explanation capability to explain why these ratings had been given. To address this we have included an explanation facility to explain why a particular chemical is given a higher rating than another in terms of stage, harshness of the chemical and basic costs.

Siratac lacked any economic content, as did early versions of entomoLOGIC. This was also a major source of concern for growers, who complained that many of their spray decisions are made on the basis of chemical cost. To accommodate chemical costs a new function was developed in entomoLOGIC which lists all currently registered chemicals and allows the user to enter the \$/ha cost of applying these. These costs are then displayed with recommendations after each run of the expert system allowing cost to be used as a basis for chemical selection.

At present entomoLOGIC does not incorporate the Siratac crop and *Heliothis* models. This greatly simplifies data entry (i.e. no fruit counts), but growers believe that it limits decision making since there is no linkage of pest damage and fruiting models, no ability to predict pest development over subsequent days after an insect count nor any detailed analysis of crop development. However, results of field testing of entomoLOGIC decisions against Siratac indicate that in most cases spray decisions and chemical selection are similar (Table 1). Researchers are now re-evaluating the relevance of the crop model for pest management decisions and for now the fruit model has been omitted from entomoLOGIC altogether. Under a new project "Development and field testing of micro-computer cotton management packages" we will be developing a version of entomoLOGIC that incorporates the *Heliothis* development and mortality models from Siratac. This version of entomoLOGIC will then be evaluated against the existing version to note any differences in disk space requirements and decision making.

An unpublished survey of computer ownership and use in the Australian cotton industry conducted for SIRATAC Ltd found that, of those growers who owned computers, 64% owned IBMs or IBM clones while only 28% owned a Macintosh. The choice of Macintosh and HyperCard for the prototype of entomoLOGIC was deliberate due to the minimal amount of time available to develop a high quality interface. One IBM owner was so impressed with a demonstration of entomoLOGIC that he bought a Macintosh to run it! However, we are committed to produce a commercial version for the IBM and work has now begun on this.

Further work on the entomoLOGIC project is still needed to:

- (1) Conduct more extensive field testing of entomoLOGIC
- (2) Develop a version of entomoLOGIC that incorporates the *Heliothis* development and mortality models from Siratac and conduct evaluation tests of this version against the existing version

- (3) Complete a series of validation tests comparing the recommendations of the entomoLOGIC expert system against existing standards (Siratac), users and human experts
- (4) Continue design and implementation of an IBM version of entomoLOGIC

This work will all be conducted in CRDC project "Development and field testing of micro-computer cotton management packages".

**Publications:**

Cox, P.G., S.L.Griffin and K.D.Brook (1991). entomoLOGIC, an expert system for cotton pest management: the development of a technology. Submitted

Wells, A. and Marsden, S. (1989) Hydrologic - A new approach to irrigation management. The Australian Cottongrower, Vol 10, No. 3. pp 7-9.