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Cotton Research and Development Corporation

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Research Organisation: CSIRO Plant Industry

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A final report prepared for the Cotton Research and Development Corporation

FINAL REPORT RECEIVED

1. Introduction

Since 1991 CRDC has supported the development of micro-computer based decision support systems, entomoLOGIC and hydroLOGIC. EntomoLOGIC has replaced SIRATAC for insect pest management and has also broadened the user base to include many private consultants. It is being continually updated to incorporate the latest pest management research and practices.

The first release of entomoLOGIC, for the 1990/91 season, was a prototype developed on the Apple Macintosh. A revised prototype was developed for the 1991/92 season and included many additional features, including the *Helicoverpa* development model from Siratac.

The IBM compatible version of entomoLOGIC was developed in 1992. A widespread release prior to the 1992/93 season included a display at the ACGRA Cotton Conference and presentations to consultants at various chemical conferences. This was followed by a series of 10 1-day workshops in all of the major growing regions, which were well attended by both growers and consultants.

EntomoLOGIC was field tested by over 100 growers and consultants in the 1992/93 season¹. At the same time a series of commercial-scale field trials of entomoLOGIC was conducted by CSIRO in the Namoi Valley. These trials, covering 4 sites in 1992/93, aimed to evaluate a soft approach using only selective chemicals (eg Bt and Chlorfluazuron) and also to demonstrate the value of entomoLOGIC as an aid to decision making. The trials were visited by large groups on field days and aroused considerable interest. Warwick Madden is conducting an expanded series of large scale trials in the 1993/94 season, covering 5 sites in the Lower Namoi, Upper Namoi and dryland (Edgeroi).

The hydroLOGIC program² was also released commercially for the 1992/93 season. This program has always aroused considerable interest in the industry, particularly among consultants, with its what-if simulation capabilities. Sales of hydroLOGIC were initially slow, but there are now around 100 registered users after CSIRO assumed full responsibility for its distribution.

EntomoLOGIC versions 1.5 and 1.6 were released for the 1993/94 season and contained a much greater range of features including the *Helicoverpa* development model, previously only in the Macintosh version. It also incorporates a new sampling system and management thresholds for mites developed over the last 6 years by Lewis Wilson at Narrabri. Aspects of the new insecticide resistance management strategy for summer crops have also been incorporated, including support for the *Helicoverpa* speciation kit, developed by CSIRO Division of Entomology.

2. Objectives

To continue the development and validation of a series of micro-computer based decision support packages (initially hydroLOGIC and entomoLOGIC) under the generic name CottonLOGIC.

3. Results and Discussion

Staffing

Mr Lance McKewen B.E. (Hons), Grad. Dip. Bus. Sys.	Senior Research Scientist CSIRO funded	80%
Mr Warwick Madden B. Sc. Agr.	Experimental scientist	100%

Progress:

This project commenced on the 1st July, 1991. Since that time the following has occurred:

- (1) A comparison of the recommendations of entomoLOGIC against those of SIRATAC has been completed using the results from field testing entomoLOGIC during the 90/91 cotton season. In most instances, the two systems gave almost identical recommendations. However the field testing highlighted the reluctance of most growers to follow suggested recommendations or thresholds. This highlights the need for the on-farm demonstration trials of pest management systems.

- (2) Changes have been made to the program structure and interface of the Macintosh version of entomoLOGIC in order to speed run time and improve user friendliness in response to the results of grower assessment of the package in the 90/91 season.
- (3) Changes were made to the User Manual of entomoLOGIC to document changes as in (2).
- (4) A version of entomoLOGIC has been developed that incorporates the *Heliothis* development and mortality models from SIRATAC. Evaluation of this version against the older version to note any differences in disk space requirements, run time and decision making was completed by the end of the 91/92 season.
- (6) Stuart McFarlane was appointed in May 1991 to design and implement an IBM version of entomoLOGIC. Software for the development of the IBM version was purchased and evaluated and a design document for the recoding of entomoLOGIC for the IBM was completed. This version was completed in time for release at the 1992 Cotton Conference (August 1992), two months ahead of schedule.
- (7) Lance McKewen was appointed in late December 1991 as project leader for the development of decision support packages.
- (8) Warwick Madden was appointed in June 1992 to maintain and develop the Macintosh version of entomoLOGIC and to conduct large scale pest management trials.
- (9) In September 1992, workshops on entomoLOGIC and hydroLOGIC were held in all growing regions. Over 100 copies of entomoLOGIC were distributed for evaluation during the 1992/93 season. The response from consultants was particularly pleasing.
- (10) The arrangement with Neutron Probe Services to market hydroLOGIC was terminated. Responsibility for marketing and support of hydroLOGIC reverted to CSIRO.
- (11) Insect sampling cards⁴ designed to be used with entomoLOGIC were developed by Warwick Madden after consultation with leading growers and consultants.
- (12) In October 1992, three large scale pest management trials using entomoLOGIC commenced in the Wee Waa / Merah North area. A similar trial also commenced on the Leitch block at Myall Vale. A series of pest management trials in Queensland is also using entomoLOGIC as a framework.
- (13) In January 1993, a group of consultants visited the trial sites at Myall Vale and Merah North to inspect pest management trials.
- (14) In March 1993, approximately 150 participants in the Namoi Valley field day visited the trial at Havana (Merah North) to inspect both IPM and conventional treatments. The IPM treatment later yielded 8.5 bales/ha.
- (15) At Unfaan (Wee Waa) the IPM treatment managed by entomoLOGIC yielded 8.7 bales/ha.
- (16) The entomoLOGIC Development Group was formed in July 1993, with representatives of users, consultants and grower associations from most regions. Mr Bruce Pyke is the chairman of EDG.
- (17) In October 1993, Stephen Klinge replaced Stuart McFarlane as programmer.
- (18) entomoLOGIC 1.5, for the 1993/94 season was released. It included the *Helicoverpa* development model and a new sampling system and management thresholds for mites developed over the last 6 years by Lewis Wilson at Narrabri. Aspects of the new insecticide resistance management strategy for summer crops were incorporated, including support for the new *Helicoverpa* speciation kit, developed by CSIRO Division of Entomology.

- (19) In October - November 1993 a series of 9 workshops was held in all major growing regions to explain the new version of entomoLOGIC and receive feedback from users. The total number of registered users of entomoLOGIC grew to around 150.
- (20) In October 1993 a new series of large scale pest management trials, managed using entomoLOGIC, was commenced. There are currently 5 sites in the Boggabri, Edgeroi, Merah North and Myall Vale (Leitch) areas, although the Leitch trial was badly hailed.
- (21) In December 1993, entomoLOGIC 1.6 was released and distributed to all users of version 1.5.
- (22) In January 1994, following a series of EDG meetings in Moree, Myall Vale and Warren, a draft specification for entomoLOGIC 2.0 was developed, including the OZCOT crop model (see Appendix).

4. Discussion

At the completion of this project, there were around 150 registered users of entomoLOGIC, comprising mostly cotton growers and consultants. This is expected to increase as the program develops and becomes more attractive to potential users. The majority of users in the 1992/93 season attended the workshops in late 1993 and updated to the new version for the 1993/94 season. This indicated a high rate of acceptance of the program, even in its initial form.

EntomoLOGIC has also been adopted as a standard for managing integrated pest management trials by other researchers and collaborating consultants. The entomoLOGIC Development Group allows grower associations, consultants and entomoLOGIC users to participate in planning and setting priorities for future versions of the program.

5. Conclusions, Recommendations and Application to Industry

Recommendations

1. Continue to develop entomoLOGIC and related management packages incorporating the latest research results and management practices.
2. Validate entomoLOGIC and demonstrate IPM systems on a commercial scale.
3. Promote the continued adoption of entomoLOGIC and provide training and support for growers and consultants in all regions.

6. Communication of Results

Results of this work have been disseminated through the distribution and usage of the computer programs and associated user documentation. Annual workshops and training courses have been held in all growing regions to support users of the programs.

Progress has been publicised with articles in the Australian Cotton Grower. Presentations and detailed computer displays were held at the World Cotton Conference and at the ACGRA Cotton Conference 1992-1996. Field day groups have visited the sites of the commercial scale field trials in each of the seasons since 1992/93.

References:

1. McKewen L.D. McFarlane S.D. and Madden W.R., "entomoLOGIC and hydroLOGIC - What's Happening?", Proc. 6th Australian Cotton Conference, Broadbeach, 1992, pp 323-327.
2. Wells A.T. and Marsden S., "Hydrologic - a new approach to irrigation management", The Australian Cottongrower, Vol. 10, No. 3, 7-9, 1989.
3. Wells A.T. and Hearn, A.B., "OZCOT: A Cotton Crop Simulation Model for Management", Mathematics and Computers in Simulation 33 (1992) pp 433-438.

4. Madden W.R., "Popular entomoLOGIC insect sampling cards revised", The Australian Cottongrower, Vol. 14, No. 5, 82, 1993.

7. Appendix

A. BUDGET

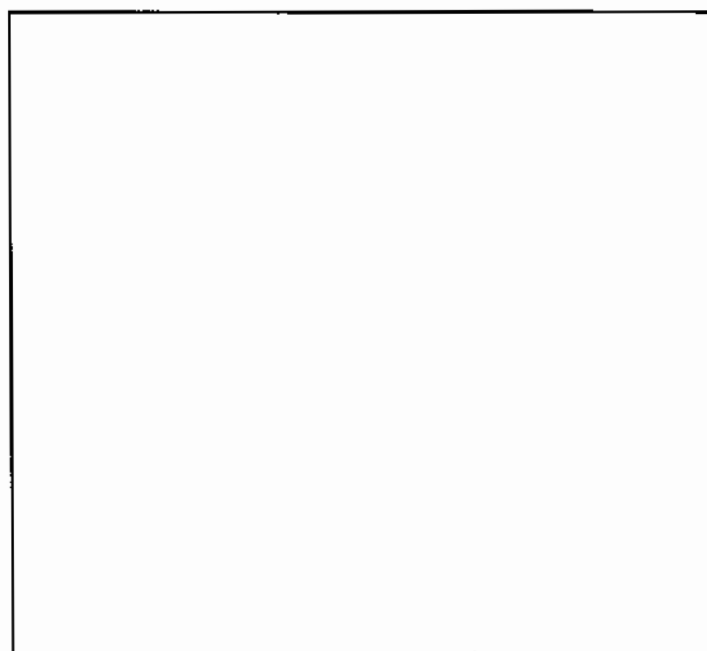
B. ADDITIONAL SUPPORTING DATA

CSIRO - Cotton Research Unit



CSIRO Plant Industry

Requirements Document



entomoLOGIC 2

Version 1.0.2

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Introduction

Much knowledge has accumulated within the cotton industry, including the results of research undertaken by CSIRO and the NSW Department of Agriculture. EntomoLOGIC is one vehicle by which this knowledge can be made readily available to cotton growers and their advisers (users of entomoLOGIC).

Objectives

The main objective of entomoLOGIC is *technology transfer*, ie. making accumulated knowledge readily available to and useable by cotton growers and their advisers. This knowledge includes:

- Methods for more efficient (and, perhaps, more accurate) counting of pests in cotton crops
- Recommendations on acceptable and unacceptable levels of pest infestation
- The *Heliothis* modelⁱ, for prediction of the development of a *Heliothis* population
- Analysis of Mite population and corresponding recommendationsⁱⁱ
- The OZCOT crop fruiting modelⁱⁱⁱ
- HydroLOGIC water model
- The Pest Management Strategy^{iv}

To aid in the use of this knowledge, entomoLOGIC will comprise a computer database program with such methods incorporated. It will cater for simple entry of data required to use the various methods, storage of such data, storage of results, and presentation of any data and results of interest to the user.

EntomoLOGIC will only serve well as a method of technology transfer if it is *seen* to be useful to cotton growers and consultants. To this end, some extra functionality may need to be built into entomoLOGIC.

Analysis & Reporting

The system will feature a reporting facility for the display of various entered and derived data. It will also recommend action be taken under certain circumstances. The methods of analysis are outlined below. Ongoing research may lead to changes in methods and parameters.

Reporting will take two forms: 'daily' reports to show the current state of the crop; and 'season' reports, to display data pertaining to the season "to-date".

Presence-absence sampling

Many insects can be sampled binomially (on a presence-absence basis), with the insect count converted into a numbers-per-metre density. Most analysis relies on knowing the insect density in numbers per metre or numbers per plant. Binomial sampling is performed on whole plants until squaring (first fruit appears on the plant), then on terminals only.

Heliothis

Conversion of binomial samples for *Heliothis* will use methods that have been recently developed within CSIRO^v.

Other binomial samples

Conversion of other binomial samples to mean densities uses the following method, based on the routine "ProxBA" from Siratac^{vi};

Simple pest thresholds

Pest infestation levels, and projected levels from the heliothis model, will be compared to predefined "thresholds". Pest populations regarded as being unacceptable will be flagged. The user will be able to define custom thresholds. On-screen display will always display the "research" based thresholds, and optionally the custom ones. Printouts may show either or both sets of thresholds.

Heliothis model

The heliothis model used in Siratac and EntomoLOGIC 1.6 will be available in EntomoLOGIC 2. Parameters may need to be revised, based on recent research.

Heliothis speciation

Data from the Lep-Ton^{vii} kit will be used to assess the infestation level of *heliothis armigera*, and likely resistance to sprays. The most basic implementation would follow the same methods as the published "stop-go" charts.

The user will be able to specify resistance and hatch-rate parameters. These parameters will be included with any display or printout of this analysis.

A better result may be obtained by incorporating the heliothis model, or at least using hatch-rate parameters from the model.

Using the heliothis development model to compare pre- and post-spray infestations, actual resistance levels could be calculated. This is not an initial requirement, but should be considered in future modelling.

Mites

Lewis Wilson's mite analysis, as appears in EntomoLOGIC 1.x, will be available in EntomoLOGIC 2. Lewis will be consulted for an update, including sensitivity to unexpected changes in population (eg dramatic drop), and fitting a better curve to the given data (a straight line is presently used).

Crop and water models

The crop and water models are not part of the base program, but will be neatly integrated for tactical use. The models will be used to predict yield and harvest date, and for irrigation scheduling. Later, the models will help assess insect damage and likely consequences of insect management decisions.

User interface

As entomoLOGIC is a commercial product, its use should be as straight-forward as possible. Attention must be paid to the way end-users work to avoid frustrating the users with a tedious interface.

General considerations

Data entry should be made easy and flexible. Users may wish to enter (say) a string of insect counts for a number of fields. Alternately, they may prefer to enter both insect count and damage data and then view a graph of insect pressure, all on the one MU. With this in mind, a single action should be all that is required to move from one part to another, holding all other aspects constant.

Any selection of a date should be easily set to "today", without hindering multiple actions on a previous date.

Selection or entry of a *year* should be unambiguous. Where the data already exists and is being selected, the preferred format is (eg) "93/94". When specifying a year which cannot be selected from a list, terms such as "planting year" or "picking year" would be helpful. Alternately a "spin button" could be used for selecting a year, using the "93/94" format.

Many users will already be familiar with previous versions of entomoLOGIC. It would be preferable not be required to learn a completely new user interface.

Management Units

Any operation that can be performed on a field will, if valid, also be possible over a whole MU. In some cases the MU will be treated as a whole, in others the component fields will run as a "batch", and where possible the choice of either will be available to the user.

"Whole Farm" will be available as an MU.

Retrieving data

The system will provide simple means for viewing and printing summaries of the various groups of data, in both daily and seasonal reports.

Daily Reports

These reports may not be produced every day, but will describe the status (current or historical) of:

Insect pressure (daily)

For a field, on a given date, list insect pressures with their individual thresholds. Counts over threshold will be marked. Such markings will be different for research and user thresholds.

The list will also describe:

- The date, purpose and products of the most recent spray on the selected field
- Any comments entered with the most recent check
- Simple output from (as appropriate):
 - Heliiothis model predictions for the next 3 days
 - Mite analysis
 - Heliiothis speciation analysis

Insect status table (daily)

For a given date, or range of dates, a table will show, by field or MU, the pressures of major pests, tip damage, the date and chemicals in the last spray, and any comments that relate to the corresponding check. It would be advantageous for the "major pests" and other fields in the table to be user-selectable. Thresholds will also be available in the table.

Season reports

The system will provide simple means for viewing and printing the following reports progressively, and at the end of the season.

Insect pressure (season)

A line graph of insect pressure on a given field, during a particular season, or progressively for the current season.

The user will be able to select a number of insects and insect groups from a list. The option to overlay sprays on the insect pressure graph will also be available.

The insects / groups will include *at least*:

- Every individual insect
- Heliiothis eggs
- Heliiothis larvae (vs+s, m+l, all)

- Minor pests (early season)
- Minor pests (late season)
- Mites (A-equivalent and proportion)

Chemical usage (season)

Table and pie graph of chemical usage by cost, for a given field or MU, during a particular season or between definable dates.

Table and pie graph of chemical usage by quantity (Litres), for a given field or MU, during a particular season or between definable dates.

Pie graph of chemicals by spray-ha (area × sprays), for a given field or MU, during a particular season or between definable dates.

Sprays (season)

A table will list all spray information on selected fields during a selected date range, sorted by date and field. The sort priority between date and field will be selectable.

Data storage

Entities and relations

The following is a description of data to be stored by entomoLOGIC. Much of it is required for the various analyses described in section 2.1. Other data is stored purely for user convenience (ie book-keeping purposes).

For each **entity** listed, its attributes are shown in *italics*. The attributes shown in ***bold italics*** are the key attributes, from which the other attributes can be derived. The **name** of any entity that has one is implicitly a key attribute.

Regions

A region:

- has a name
- has *season start* and *season stop* dates, and *season length*
- has pest management strategy *stage 2* and *stage 3* start dates
- has a season-by-season history of these parameters

The regions defined for Siratac or EntomoLOGIC 1.x will be used, subject to fitness for the various analyses.

Farm

The system will provide simple means of defining a farm and its fields. Farms will be re-nameable and deleteable, with suitable warnings.

A farm:

- has a name
- belongs to a *region*
- has an *address*
- has an *owner*
- has a *manager*

NB: The address, owner, and manager, may contain more than 1 line of text, including a full address and telephone numbers.

Fields

The system will provide simple means for entering and updating crop data. This will be field based, with all crop data for a given field available on-screen simultaneously.

A field:

- has a name
- belongs to a *farm*

- and for each *year*
- has an *area*
- has a *variety*, and a *plant stand*
- has a *progress* described as "behind", "average", or "ahead"
- has dates for *sowing*, *4 true leaves*, *first square*, *first boll*, *1% open*, *20% open*

Management Units

A management unit (MU):

- has a name
- belongs to a *farm*
- contains a list of *fields*

Variety

A variety:

- has a name
- is or isn't an *okra-leaf* variety

All varieties known to NARS will be listed.

Damage

The system will provide simple means for entering and changing damage information. The method for entering this data should bear semblance to usual damage reporting and recording methods.

Damage is sampled at the same time as insects are, and resultant data will be viewed together, so it may be worth storing damage data with insect data.

Damage samples:

- exist for a *field* on a *date*
- describe *setback* due to herbicides/Rhizoctonia as "none", "mild", "moderate", or "severe"
- have a *total* number of plants sampled
- have numbers of plants with:

Healthy terminals

Primary tips damaged

Primary tips black

Primary tipped out and second healthy

Primary tipped out and second damaged

Primary tipped out and second black

Pests

A pest:

- has a name
- has a *unit* of measure

There will be a table of various parameters for analysing pest pressures and advising control action. (eg. threshold, based on time of season, etc.)

Note that a "pest" as defined in this table may not strictly be an insect. It could, for example, be a measure of the effect of some pest (honeydew for aphids).

The pests and their units are:

Pest Name	Units
Heliiothis W. Eggs	/ metre

Heliothis B. Eggs	/ metre
Heliothis VS.Larvae	/ metre
Heliothis S. Larvae	/ metre
Heliothis M. Larvae	/ metre
Heliothis L. Larvae	/ metre
Heliothis armigera	proportion of heliothis
Tipworm W. Eggs	/ metre
Tipworm R. Eggs	/ metre
Tipworm S. Larvae	/ metre
Tipworm L. Larvae	/ metre
Mites (Wilson)	proportion
Mites (A)	proportion
Mites (B)	proportion
Mites (C)	proportion
Mirids (Nymph)	/ metre
Mirids (Adult)	/ metre
Apple Dimpling bug	/ metre
Aphids (Insect)	proportion
Aphids (Honeydew)	proportion
Small Armyworm	/ metre
Large Armyworm	/ metre
Roughies	/ metre
Loopers	/ metre
Thrips	/ metre
Whitefly	proportion
Green Vege Bug	/ metre
Jassids	/ metre
Pinkies	/ metre
Predators	/ metre

Pest samples

The system will provide simple means for entering and changing insect check data. The method for entering this data should bear semblance to the entomoLOGIC insect sampling cards (CSIRO 1992) without sacrificing ease of use. Counts should be entered in a manner corresponding to standard methods of sampling.

- *Heliothis*, *Predators*, *Rough Bollworm*, *Loopers*, *Green Vege Bug*, *Jassids*, *Aphids* and *Thrips* may be sampled and entered binomially (presence-absence over number of plants sampled), or directly, by numbers found over number of plants or metres sampled. Binomial sampling is performed on whole plants until squaring (first fruit appears on the plant), then on terminals only.
- *Mirids*, *Tipworm*, *Pinkies* and *Armyworm* will be sampled and entered by numbers found over number of plants sampled or number of metres sampled.

Pest samples:

- are taken on a *field* on a *date*
- have a *sample size*, ie the number of plants sampled. This is repeated for extra sampling methods, eg number of heliothis tested for speciation, number of samples for Wilson mite analysis.
- Any *pest* found
- has a *count*

Chemical Ingredients

A chemical ingredient:

has a name

The chemicals to be listed are:

Chemical

Acephate	_
Azinphos ethyl	_
B. Thuringiensis	_
Chlorfluazuron	_
Chlorpyrifos	_
Demeton-S-Methyl	_
Dimethoate	_
Endosulfan	_
Formothion	_
Methomyl	_
Monocrotophos	_
Omethoate	_
Parathion	_
P.B.O.	_
Profenofos	_
Propargite	_
Pyrethroid	_
Sulprofos	_
Thiodicarb	_
Thiometon	_

Chemical costs may be updated by the user. The cost of chemicals for a particular application will be stored with other application data.

Spray products

The system will provide simple means for entering and changing information regarding spray products. In addition to known commercial products, the system will recognise generic products named after the active ingredient(s).

A spray product:

- has a name
- contains a number of *chemicals*, each with a *proportion* of the total mix
- has a *unit* (Litres or kg)
- has a *cost* in \$/*unit*

Spray purpose

Each *spray application* can be matched against one or more *purposes*.

Recognised spray purposes for analysis and reporting are:

Herbicide
Insecticide
Miticide
Defoliant
Spraying oil

Spray Applications

The system will provide simple means for entering and changing spray application records.

A spray application:

- is over a *field*
 - NB: Applications may be *entered* for a whole *MU*, but the information will be stored by field, as per insect counts.
- occurs on a *date*
- occurs at a *time* of day
- has a method of *application* described as "aerial" or "ground"
- has a *percentage banding* (0-100%) or a *swath width* (0-100m).
- occurs in *rain* conditions described as "dry", "light rain", "heavy rain", or "???"
- occurs during *wind* described as "steady", "variable", "calm", "windy", or "???"
- has an *application cost* (\$/ha)
- has an *area sprayed* (defaults to total area of field or MU)
- may bear a *comment* of up to at least 255 characters of text.
- has one or more *purposes*
- has a chemical formulation: EC or ULV
- uses a number of *spray* products (the facility to enter a new product will be available at the point of entering / selecting a spray product). Each spray product used:
 - has a *rate* of application (L/ha or kg/ha) and a *total volume* (0-9999L). Only one of these values need be entered, the other will be calculated.
 - has a *spray cost* (\$/L or \$/kg), with a default value copied from the *spray* product information. (This is to cope with changing chemical costs)

Architectural provisions

Updates to existing data and methods

As research continues, and with other factors, some "fixed" parameters will need to be modified. These may include:

- Season parameters according to *Region*
- New crop *varieties*
- New *pests*, and updated *thresholds* for spray action
- New *chemicals*

These parameters will be kept up-to-date for each release of entomoLOGIC. Records for previous seasons should not be destroyed or made invalid by such updates, so these items will need to be dated:

- Annual season parameters according to *Region*.

Extensibility

There is much knowledge relevant to cotton crop and pest management that has not been incorporated into entomoLOGIC. New methods of analysis and modelling are also becoming available. There should be provision to add such knowledge to the system quickly and easily, without damaging historical records.

Openness

Accessing basic data

Data will be stored in, or exportable to, a standard format to make it easily accessible using common database tools. This allows farm managers and consultants with particular needs to carry out any additional analysis, and to incorporate entomoLOGIC data into reports.

Exporting text-based analysis

The system will provide simple means for "exporting" any analysis in a simple text format. eg. for incorporation into a consultant's report.

Exporting graphical representations

The system will provide simple means for "exporting" the various graphical views of its data using standard MS-Windows methods.

Importing older EntomoLOGIC data

EntomoLOGIC 2 will provide, internally or as a separate utility, means of importing data created using EntomoLOGIC 1.5 or later.

Multiple databases

EntomoLOGIC 2 will provide means of using and maintaining multiple databases in different directories.

Assumptions

Host system requirements

EntomoLOGIC 2 will run on intel™-based computers running MS-Windows™ with virtual memory available. For reasonable performance, a '386 CPU with 4MB of RAM and VGA graphics will be considered a minimum configuration. A '486 with 8MB of RAM and SVGA is recommended.

Once the MS-Windows prototype is completed, the difficulties in porting to the Apple Macintosh will be evaluated. Should porting be fairly straight-forward, it may be considered for release in 1994/5.

ⁱHeliothis model derived from Siratac source code

ⁱⁱWilson L., pers. comm.

ⁱⁱⁱHearn A.B. 1994 "OZCOT: A Simulation Model for Cotton Crop Management", *Agricultural Systems* **44** (1994) pp 257-299

^{iv}As advised by Neil Forrester

^vDillon G.E., Fitt G.P. 1992 "Reassessment of sampling relationships for *Helicoverpa* spp. (Lepidoptera: Noctuidae) in Australian cotton."

^{vi}Wilson, Room 1983" Clumping Patterns of Fruit and Arthropods in Cotton, with Implications for Binomial Sampling"; Brook, Hearn "SIRATAC program content" [p 29]

^{vii} The "LepTon™ Test Kit" is available from Abbott Laboratories.