MANAGEMENT TOOLS FOR INTEGRATED PEST MANAGEMENT - entomoLOGIC's Role

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Introduction

Two years ago, the computer program entomoLOGIC[1] was first made widely available to cotton growers and consultants. It was designed to assist in management of insect pests on cotton through the use of models of crop and pest development and other technology including a valuable record keeping capability.

These functions serve a common purpose; better decisions can be made with the experience and understanding gained by good records of what has occurred in the past, and good reporting of what is currently happening on the farm. The models and other new technology can then assist in analysing the immediate crop and pest situation.

Trends in cotton insect management

The management of insect pests in cotton will change dramatically with the commercial introduction of transgenic varieties. However the widespread adoption of these varieties may not occur until the turn of the century.

In recent years, the increase in resistance of *Helicoverpa armigera* to synthetic pyrethroids and, more recently, endosulfan, has caused changes in pest management approaches. These have been reflected in the resistance management strategy, which has been voluntarily adopted by virtually the whole industry over the past decade[2]. Current concerns about resistance to other chemical pesticides (eg Bt and profenofos) have led to additional guidelines and restrictions being included in the strategy.

A significant change in approach to resistance management occurred in the 1993/94 season, when the window for application of synthetic pyrethroids was increased from 35 to 50 days. This move was based of the availability of the *Heliocoverpa* identification kit, which allows the user to determine whether the target population is predominantly the susceptible *H. punctigera* species, in which case pyrethroids or endosulfan can be effectively used, or contains a significant proportion of *H. armigera*.

The usage of the identification kit is expected to be more widespread in the 1994/95 season, and accordingly the window for use of synthetic pyrethroids has been extended to the beginning of the season in most areas. Thus the management of resistance has moved from a biological basis (allowing only one generation of *Helicoverpa* to be exposed) to a technological approach, involving species identification of the target population and appropriate selection of pesticide chemistry[2].

There is no doubt, however, that the development of resistance is causing the cost of pest management in cotton to rise, partly because the cheapest options cannot always be used. In addition to substitution of more expensive chemicals, there are costs associated with the species identification and the cultivation of overwintering pupae.

There is no evidence that the widespread adoption of Bt transgenic varieties will significantly reduce the complexity of pest management (hopefully it will reduce the costs). Certainly for most of the season there will be no need to spray for*Helicoverpa*, except perhaps a carefully chosen spray late in the seasou to break resistance. However pests which are of lesser importance at present, or which are normally contolled in conjunction with *Helicoverpa*, will assume major status. These will probably include mirids and other sucking pests. There are also likely to be complex procedures to reduce the selection of *Helicoverpa* for resistance to the Bt plants. These may include refuge crops and other techniques considered unusual in terms of current practice[3]. Cultivation of pupae will remain a critical tactic in managing resistance.

The next 5 or 6 seasons, before widespread adoption of transgenic cotton, will be a period of transition for the Australian cotton industry as new tactics are employed to contain the costs of pest management and to retain effective control of major pests. These new tactics will generally have a technological, or IPM, basis, including increased use of beneficial insects to control the major pests[4], possible augmentation of predators and the use of food sprays as described by Mensah[5]. The choice of varieties for resistance to pest attack will be equally important as selection for resistance to various diseases[6].

In any case, the days where a crop can be kept completely "clean" of pests are probably gone because of the effects of resistance and cost of control, and this alone is probably not a bad thing, because many modern varieties can tolerate measurable pest pressures for much of the season without loss of yield or earliness, as the current work has demonstrated.

entomoLOGIC - a vehicle for the technology of the present and the future

entomoLOGIC is a computer based system for assisting with management of cotton crops. Its primary purpose is pest management, although modules for predicting yield, scheduling irrigation, and recording field operations have recently been added. entomoLOGIC is designed as a tool for use by anyone involved in pest management or farm management as an aid to decision making; it is not a substitute for skilled agronomists.

entomoLOGIC is primarily a platform for applying current technology in pest management, and like the technology described above, it is continually changing as new techniques emerge. It does not impose the use of any particular technology on the user, but it provides the option of adopting new techniques proven in commercial trials.

Record keeping - and important technology for decision making

Comprehensive record keeping is an important technology in management, because it allows the manager to review the effectiveness of current and past practices. In insect management, entomoLOGIC can be used to maintain a permanent record of pest pressures on a field basis. In combination with spray records, this enables the user to review the performance of pesticides and the choice of action thresholds. Spray records are also important for monitoring compliance with guidelines of the resistance management strategy.

With the release of Version 2 at this conference, entomoLOGIC can also be used for keeping records of all crop inputs, including fertilisers, defoliants, irrigations and field operations. It will also store data from fruit counts, probe readings and even weather records. These data can be presented in the form of graphs and reports and compared with crop yields and quality data, which are also recorded on a field basis.

Technology for pest management - entomoLOGIC's role

Insect sampling technologies

entomoLOGIC supports a range of insect sampling systems, meaning that users can enter data in whatever format suits them best. It gives agronomists the capability to use presence-absence (binomial) sampling, because it contains equations which convert these data to numbers per metre, the standard units of pest pressure in entomoLOGIC.

The presence-absence system of checking is thought by some[7] to be more consistent than counting absolute numbers. It may also be faster, allowing a greater number of plants to be checked. Its usage in the industry has been limited by the need to convert to numbers per metre, for comparison with action thresholds. These conversion equations are provided in entomoLOGIC.

Technology for management of mites

Mites, at least in NSW growing areas, are the most important pest after *Helicoverpa*. In the 1993/94 season they became the major pest of concern in these areas.

Lewis Wilson of CSIRO[8] has developed a system of monitoring mite populations and assessing their potential to cause economic damage. This system would be familiar to most agronomists in the affected areas. The new system of monitoring involves a specific mite sample, in which normally 100 leaves are taken along the row length and simply scored on the basis of presence or absence of mites. Thus the sampling system itself is very simple. With successive samples the rate of increase of the mite population can be assessed.

By taking into account the season length and the remaining time for damage to accumulate, the loss of yield due to the developing mite population can be assessed. Because this relationship has been developed empirically (derived from extensive experimental data) it requires lookup tables[8] or a computational approach. These calculations are performed by entomoLOGIC so the user has only to enter the raw presence-absence counts. The rate of increase, date of exceeding the nominal threshold and the potential yield loss are estimated by the program, which also provides a simple advice message explaining the situation. The final choice of action, as always in entomoLOGIC, is left up to the user.

Technology for managing *Helicoverpa*

The 1993/94 season saw the commercial introduction of the *Helicoverpa* identification kit, LepTon®, originally developed by CSIRO Division of Entomology[9]. By determining the proportion of the potentially resistant *armigera* species in the target population, the user can decide whether or not to use endosulfan or synthetic pyrethroids alone. This decision process requires inputs of egg and larval pressure, egg mortality rates, proportion of *armigera* likely to be resistant as well as the raw data from the identification test. The LepTon® kit contains lookup tables to assist in making this decision.

The same technology is incorporated in entomoLOGIC, so that the user need only enter the raw data from the LepTon® test. The pressure of potentially resistant larvae is calculated, and a simple advice message provided, corresponding with the green, yellow and red regions of the lookup charts. At present the decision process in entomoLOGIC is identical with that in the lookup tables, to maintain consistency between the two forms. However in the future, entomoLOGIC could be used to estimate egg mortality, for example, based on expected climatic conditions.

A model for predicting *Helicoverpa* pressures

entomoLOGIC contains the Helicoverpa development model, which predicts egg and larval pressures over a 3 day outlook from the most recent counts. Mortality and development rates are based on expected climatic conditions, taking into account the region and the time of the season. The model indicates whether larvae are likely to be over threshold before the next check, allowing action to be taken at the favourable stages of egg or newly hatched larvae. Sprays can also be avoided if the model indicates that mortality will cause pressures to drop below threshold over the next 3 days. This has led to practical savings during commercial trials. Users are urged to use the record keeping functions to assess the performance of the model under local conditions and evaluate it as an aid to decision making.

Testing the curreut technology under field conditions

In order to test this technological approach, large scale commercial trials have been conducted over the past two seasons in collaboration with leading growers and consultants in the Namoi Valley. In the first instance, commercial scale plots managed using entomoLOGIC were compared with the best commercial practice. In each trial, the two treatments were replicated twice in an attempt to eliminate other variations within the fields. Each plot was sufficiently wide to minimise the effects of spray drift and careful attention was also received from aerial spray operators.

In the "Soft" plots (managed with entomoLOGIC), broad spectrum pesticides including synthetic pyrethroids and organophosphates were avoided in an attempt to maximise the activity of beneficial insects. It was hoped that by preserving predators, *Helicoverpa* or mite sprays could be reduced. The trial also investigated whether selective pesticides such as Bt and chlorfluazuron could be used effectively as alternatives to the broad spectrum compounds. Endosulfan was still used extensively on the Soft treatment in the 1992/93 season.

The trials were checked for insects twice weekly and spray decisions made using the standard thresholds in entomoLOGIC. The *Helicoverpa* model was used to check whether larvae would be over threshold in the days following each check.

Two replicated trials were completed in the 1992/93 season. Both were high yielding crops, but showed significant differences in yield and number of sprays applied between the "Soft" (managed using entomoLOGIC) and Commercial treatments. In one case the Commercial treatment (9 sprays) outyielded the Soft (8 sprays) by 8%, while in the other the Soft (7 sprays) outyielded the Commercial (11 sprays) by nearly the same margin (see Tables 1(a) and 1(b) below).

Havana 1992/93	Commercial	Soft
No. of sprays	11	7
Yield (Bales/ha)	7.9	8.5

Table 1(a) Summary of results from Havana trial 1992/93

Unfaan 1992/93	Commercial	Soft
No. of sprays	9	8
Yield (Bales/ha)	9.4	8.7

Table 1(b) Summary of results from Unfaan trial 1992/93

Testing entomoLOGIC for conventional or IPM conditions

After encouraging results from the 1992/93 season it was important to test the performance of entomoLOGIC for management using conventional pesticides as well as further investigate emerging IPM technology. For the 1993/94 trials the commercial treatment was replaced by a "Hard" treatment, using conventional pesticides, but managed using entomoLOGIC. The design of the trials and the need to minimise spray drift limited the number of possible treatments to two.

The "Soft" treatment was made "softer" by reducing the use of endosulfan to further encourage beneficial insects. This treatment relied entirely on selective pesticides, particularly Bt, chlorfluazuron and propargite. The spray program in its entirety did not necessarily represent an alternative to conventional practice, but it served to test whether these compounds could be used as alternatives to broad spectrum pesticides and whether increased beneficial insect activity would in fact lead to a saving in *Helicoverpa* or mite sprays.

Four trials were held on private farms in the Upper and Lower Namoi regions, including a raingrown trial near Edgeroi. This followed on from the successful demonstration trial conducted by Robert Eveleigh in the previous season.

In two of the trials (Upper Namoi and Edgeroi raingrown) the differences in yield were not statistically significant. In the trial held on Havana, the two adjoining Soft plots in the centre of the field were affected by a soil condition, which also affected the rest of the field to a lesser extent. Nevertheless a satisfactory yield was obtained from the Hard plots. The Waiwera trial was interesting because of the high pressure of mites experienced. The mites on the Hard plots required control before those on the Soft, possibly due to the activity of beneficial insects in the Soft. Unfortunately, by the time the Soft treatment required spraying for mites, supplies of Comite®, the only suitable miticide, had run out. Therefore the Soft treatment was badly affected by mites and yielded 20% lower than the Hard.

The maximum difference in maturity between treatments in any of the trials was 4 days, with 2 not significantly different and in the other 2 the Soft and Hard being alternately earlier. The yield results are summarised in Table 2, below.

Kilmarnock 1993/94	Hard	Soft	Comments
No. of sprays	6	6	Hard required mite spray, not required in Soft
Yield (Bales/ha)	7.27	7.28	Yield difference not significant

Table 2(a) Summary of results from Kilmarnock trial 1993/94 (Upper Namoi)

Havana 1993/94	Hard	Soft	Comments
No. of sprays	8	8	*Soil condition affected yield ,
Yield (Bales/ha)	7.69	5.33*	mostly affected soft plots.

Table 2(b) Summary of results from Havana trial 1993/94 (Lower Namoi)

Waiwera 1993/94	Hard	Soft	Comments
No. of sprays	8	7	*Soft plots could not be sprayed for mites
Yield (Bales/ha)	6.70	5.41*	due to shortage of Comite®.

Table 2(c) Summary of results from Waiwera trial 1993/94 (Lower Namoi)

Calatoota 1993/94	Hard	Soft	Comments
No. of sprays	6	4	Very encouraging results under dryland conditions
Yield (Bales/ha)	3.72	4.04	Yield difference not strongly significant.

Table 2(d) Summary of results from Calatoota trial 1993/94 (Edgeroi, raingrown)

Discussion

Apart from the difficulties noted above, the field trials demonstrated that entomoLOGIC can be effectively used to manage insect pests on cotton with conventional insecticides. They also showed that the same system can be applied in conjunction with tactics aimed at utilising beneficial insects. Pesticides which had little effect on these beneficials were evaluated as alternatives to conventional broad spectrum compounds for control of *Helicoverpa*.

The value of beneficial insects in assisting to control *Helicoverpa* and mites has been demonstrated on a commercial scale in these replicated trials. The delaying of the mite spray on the soft treatment at Waiwera can be attributed to beneficial insects. An okra-leaf variety may have significantly reduced the damage ultimately caused by the mites. Trials involving okra-leaf varieties, particularly Siokra L22 and Siokra 1-4, have demonstrated that high yields can be obtained without loss of earliness while managing *Helicoverpa* with standard thresholds. The release of the Siokra V-15 variety is an exciting development for fields similar to the Waiwera site.

The trials held in NSW over the past two seasons have experienced relatively light *Helicoverpa* pressure. Under these conditions the activity of beneficial insects in the early season can be used with advantage to delay the first *Helicoverpa* spray. A problem occurs if it is necessary to spray with a broad spectrum insecticide to control mirids or similar sucking pests, or if an early spray is required due to a significant *Helicoverpa* egg-lay. The destruction of predators will lead to rapid re-infestation by *Helicoverpa*, requiring follow-up sprays. This effect is illustrated by a comparison of the Hard and Soft treatments at the Calatoota site, shown in Figure 1.

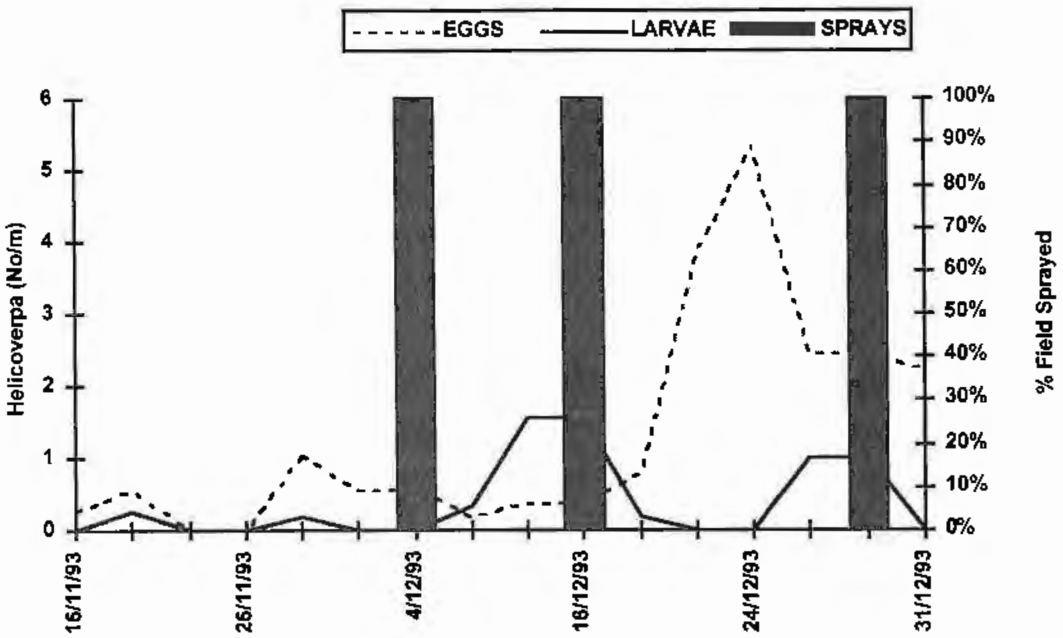

Fig. 1(a) *Helicoverpa* pressures on Calatoota Hard treatment, sprayed with endosulfan/dimethoate on 4/12/93.

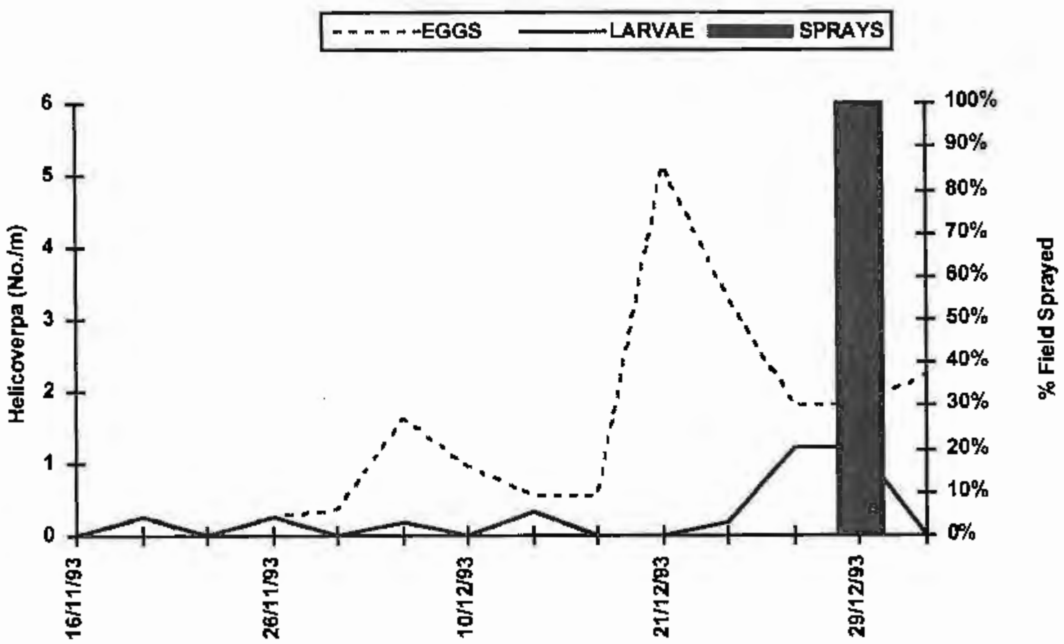

Fig. 1(b) *Helicoverpa* pressures on Calatoota Soft treatment.

A significant mirid pressure in early December caused the Hard treatment to be sprayed with endosulfan and dimethoate. No soft option was available for mirid control and it was decided not to spray the Soft at that time. The resurgence of *Helicoverpa* pressure on the Hard is clearly visible and this led to the Hard being sprayed again on 16/12/93. The lack of resurgence on the Soft treatment can be attributed to the beneficial insects.

Similar resurgence would have been observed if the field had been sprayed with endosulfan alone, for example, although possibly to a lesser extent. In the event of a significant *Helicoverpa* egg-lay early in the season, a full-rate Bt spray, with ovicide if necessary, may be a good option. This will control the hatching larvae, while allowing predators to be preserved for another couple of weeks.

Promising results for raingrown cotton

Recently there has been considerable debate about insect management strategies for raingrown cotton[10,11]. Although only limited trials of entomoLOGIC have been carried out on raingrown crops, the results have been particularly encouraging and demonstrate that entomoLOGIC is a very effective system for managing raingrown cotton using either conventional or soft insecticides. The program of raingrown trials will be expanded for the 1994/95 season.

Emerging IPM technology

Over the next 5-6 years, entomoLOGIC will be further developed to support new IPM technologies which show commercial promise. Predator augmentation and the use of food sprays to encourage beneficial insects are likely to be included. Models which allow the economic effects of Helicoverpa damage to be assessed, similar to the present capabilities for mites, are currently under development and these will be included to aid in pest management decision making.

With the widespread adoption of Bt transgenic cotton around the turn of the century, new technologies will be developed to manage the development of resistance to the BT toxins and to address the increasing importance of sucking pests. These strategies will be supported by future versions of entomoLOGIC. Trials of these management systems for Bt cotton are expected to commence in 1995.

Conclusions

entomoLOGIC is a technology-based approach to insect pest management in cotton. It currently supports technologies including record-keeping and analysis, enhanced systems of insect checking, models which predict crop and pest development and water usage and the latest systems for management of mites and indentification of *Helicoverpa* species. Trials to evaluate these technologies have been conducted over the last 2 seasons and have demonstrated their value for managing both high-yielding irrigated crops and raingrown crops. These trials will continue in future seasons.

The industry is presently in a transitional stage before Bt transgenic varieties are widely adopted around the turn of the century. Over the next few years, various strategies to enhance the activity of beneficial insects will be adopted to assist in management of the major pests. entomoLOGIC is well positioned to support these new technologies as they become commercially available. Tactics involving the use of thresholds and selective pesticides to maintain predators have already been demonstrated on a commercial scale, in recent field trials of entomoLOGIC.

entomoLOGIC will also be well positioned to support the implementation of Bt transgenic cotton, as new strategies to mauage Helicoverpa resistance and sucking pests are developed. Trials of these strategies are expected to commence in 1995.

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Comite® is a registered trademark of ICI.

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