Know-how for Horticulture™

Development and implementation of integrated pest management systems in eggplant and capsicum

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QLD Department of Primary Industries and Fisheries

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This publication is the final report for project VG00026 "Developing and Implementing Integrated Pest Management Systems for Eggplant and Capsicum" outlining the work undertaken and the outcomes achieved for the Eggplant and Capsicum industries.

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MEDIA SUMMARY

The current control of insects in capsicum and eggplant crops relies heavily on scheduled applications of insecticides. For some pests there are few or no registered products, while insecticide resistance is an increasing issue.

This project is a first in an attempt to develop Integrated Pest Management (IPM) systems in these crops. It is based on the relationship between the insect pests and beneficial insects. Other projects have concentrated on developing controls for some of the pests in these crops. The results from those projects and from personal experience, in working on insects in vegetable crops, have contributed to the final outcomes of this project.

Adoption of IPM systems based on the outcomes of this project relies on growers and crop consultants being able to identify the insects in the crops. A comprehensive and field useable book has been published and is available. It has 106 pages of information on the pests and beneficial insects and is indexed under crops and alphabetically and includes the following:

- Photographs
- Description of the insect including immature stages
- Similar looking insects
- Crops or pests attacked
- Damage or impact on pests
- Monitoring
- Biocontrols

Monitoring systems developed for insect pests in capsicum crops are effective, easy for growers and crop consultants to use with the aid of this field book, and there should be no difficulty in monitoring crops and implementing IPM systems. Softer type insecticides with minimal effect on the beneficial insects are available.

With limited control of silverleaf whitefly, the development of IPM in eggplant has not been successful. With the future release of the imported wasp parasites this may change. There is also the need to include western flower thrips studies into the IPM system as it develops in these crops in Queensland.

TECHNICAL SUMMARY

In eggplant (*Solanum melongena* L) and capsicum (*Capsicum annuum* L) the management practices for insect pests rely heavily on scheduled insecticide applications. The most important and common insects to both crops are Heliothis [*Helicoverpa armigera* (Hubner)], aphids [*Myzus persicae* (Sulzer) and *Aphis gossypii* Glover)] and eggfruit caterpillar [*Sceliodes cordalis* (Doubleday)]. Other major pests include silverleaf whitefly [*Bemisia tabaci* type B] that mainly infests eggplant and a number of thrips species [*Thrips spp.* and *Frankliniella sp*.]. Other minor insect pests belonging to a number of insect orders also attack these crops.

With limited numbers of registered pesticides in these crops, there was an urgent need to increase or diversify the number and type of registered products or alternately develop a sustainable control system, Integrated Pest Management (IPM) approach. Beneficial insect activity was significant in previous research projects exploring controls for the main pests of these crops. The common ones found were wasp parasites and predatory insects, including ladybird beetles and lacewings. A number of species of predatory bugs were also present. With the development of a pheromone for eggfruit caterpillar [*S. cordalis* (Doubleday)] and commercially available Heliothis [*Helicoverpa spp*.] pheromone lures, this allowed monitoring of the adult of those insect populations.

Successful IPM is based on control options that are economically sound, environmentally acceptable and user friendly, as well as producing a marketable product.

Outcomes from this project showed that scouting methods could determine insect numbers in capsicum crops. The main part of the plant to sample was the top 1/3 of the plant. By sampling 5 randomly selected leaves per plant with a sample size of 1 plant in 300 plants up to a maximum of 50 plants examined, would give a reasonable estimate of the insect population within that crop. If all insects were recorded then an average of 0.12 beneficial insects, mainly ladybird beetles, lacewings or parasitic wasps, would control an aphid population with an average of up to 6 per leaf. Control for Heliothis would be needed if no parasitism was recorded and an average of 5 eggs or 1 larva was counted per 10 plants. Variations to that number depended on the percentage of egg parasitism by *Trichogramma spp.* and the number of other beneficial insects that prey on them.

Pheromone trapping for eggfruit caterpillar and Heliothis adults is not a reliable indicator of their activity in the crop. Research showed that the area to check for eggfruit caterpillar is along the fruit stalk and on the fruit. This is the preferred site for egg laying. Eggs are white when first laid and develop red stripes down the side of the egg within a day. The larvae burrow into the fruit within a few hours of emerging from the egg.

To assist growers and crop consultants in identifying insects found in these crops a book, “INSECT PEST GUIDE: a guide to identifying vegetable insect pests and their natural enemies in the dry tropics” was published with numerous photographs of the insects including the immature stages. With each insect a description is given with references to similar insects, crops or insects attacked, damage inflicted on the crop or impact on the pests, monitoring and bio-controls. As well as capsicum and eggplant, it includes beans, cucurbits, sweet corn and tomato, and should be a major benefit for all growers in these vegetable industries.

Results from this project have shown that with this information, an IPM system in capsicum can be successful. This has been demonstrated in study plots, on grower properties and on research stations.

The adoption of IPM system in capsicums has been slow and this has been due to the delay in the publication of the insect booklet. Without the ability to identify the insect, as a pest or beneficial, it is difficult to adopt and implement an IPM system. Future development of IPM in capsicum crops should be directed at the involvement of growers in using the crop monitoring technique with the insect identification book.

Integrated Pest Management in eggplant crops has not been successful. Future work will need to consider softer type controls for the silverleaf whitefly. The development of IPM in this crop maybe possible, if the current release of the introduced parasite is successful.

Another potential insect problem that could jeopardise the implementation of IPM systems in both crops is that the current control recommendations for western flower thrips rely heavily on broad-spectrum insecticides.

The production of the Insect Identification Guide that covers both of these crops as well as beans, cucurbits, sweet corn and tomato is of a major benefit for all growers in these vegetable industries.

INTRODUCTION

Eggplant and capsicum are two major vegetable crops grown in Australia. The Dry Tropics region of north Queensland, between Ayr and Bowen, is the major production area. There are much smaller growing areas in the southern part of Queensland, while the other states account for less than 10% on national production (Australian Bureau of Statistics).

Both of these crops are subjected to damage from a number of insect pests (Swaine *et. al.* 1985 and 1991, Brough *et. al.* 1994) some of which are common to both crops. Pests include Heliothis, a number of aphid species, eggfruit caterpillar and silverleaf whitefly. Other insects can be present and occasionally flare up sufficiently to cause economic losses. These include thrips, mites, green vegetable bug and other sucking bugs, leaf miner, yellow peach moth, cluster caterpillar and fruit fly.

The management of the insect pests in capsicum and eggplant is generally based on scheduled pesticide applications. The number of products registered for use on these crops is limited and has been further reduced with restrictions on the use of endosulfan. This chemical is effective in controlling some of the leaf and fruit feeding larvae and the plant-sucking bugs in these crops. This has lead to an increase in the number of minor use applications to the Australian Pesticide & Veterinary Medicines Authority. There has also been resistance development in Heliothis to some pesticides (Gunning pers. comm.) and a lack of registered products to use in rotation to control Silverleaf whitefly.

Development of Integrated Pest Management (IPM) systems is seen as essential for the future sustainability of most vegetable crops. Growers adopting IPM systems can enhance industry viability through less use of harmful pesticides and enhanced market opportunity with “clean and green” produce. This not only meets consumer demand but industry can also gain community credit for its care of the environment. At the same time, a reduction in insecticide use results in less exposure of growers and their workers to harmful toxins.

IPM is a system that integrates all options for managing pest populations with the aim of reducing insecticide use while maintaining profitability and yield (Mensah *et. al.* 2002). The study reported here was aimed at evaluating the effectiveness of beneficial insects and softer insecticides while accepting that the other aspects of IPM systems would be included in the overall management of pests.

A previous project (Brown, J. 2000) identified the control effectiveness of aphid parasites and adults and larvae of ladybird beetles and lacewings. This was refined in this project by developing scouting methods, and demonstrated that these beneficial insects do achieve adequate control of aphid populations. Moderate populations of Heliothis can be managed by the activity of beneficial insects including the egg parasites, *Trichogramma spp*. Softer insecticides were identified in a related project (Kay *et. al.* 2003) as well as their lesser impact on beneficial insects. In another project (Brown, J. 2002), eggfruit caterpillar pheromone was identified and this allowed further studies of this insect. Studies on the biology of the eggfruit caterpillar showed that the egg or emerging larva should be targeted to control this pest. This is because the larvae burrow into the plant within a few hours of emergence. No parasites of this insect have been detected.

A previous study on silverleaf whitefly (White *et al.* 1998) indicated that this pest would increase in importance. This has occurred and the need to develop controls in eggplant for this pest is paramount prior to any IPM system being adopted. Investigations into silverleaf whitefly between 1997 and 1999 showed that use of insecticides to control other pests could lead to increased populations of whitefly (Franzmann 1998). This work also demonstrated that where these pesticides were withheld, populations of whitefly did not developed rapidly and remained below damaging thresholds (Brown unpublished). At present, minor use permits allow a range of pesticides to be used against silverleaf whitefly. Evaluation of a range of softer pesticides (Ark products) did not provide adequate control. A HAL funded project (VX 99003) which commenced in 1999, had a component to develop a management option based on utilising parasites. The outcomes from the release of the imported parasite in 2005 may enhance control of this pest.

The adoption of IPM systems in capsicum and eggplant has been hindered by the inability of growers and crop consultants to distinguish between some of the pests and beneficial species. This failing has meant that the impact of beneficial species could not be considered in their management of the pests. A book (Brown 2004) identifying all the insects and beneficial species with information about each was a goal of this project.

QUESTIONNAIRE

INTRODUCTION

A questionnaire (Appendix 1), formulated in conjunction with an Extension Officer, sought information from growers of capsicum and eggplant on insect pest management practices at project outset. It was mailed to vegetable growers at the start of this project to gauge the level of insect pest management presently being undertaken in eggplant and capsicum crops. The questionnaire was distributed throughout Queensland and Western Australia.

Part of the questionnaire was aimed at identifying how many growers were mainstream producers of capsicum or eggplant. This could be gauged from their responses to the question as to whether these crops were their main source of income or whether these crops were part of a larger farming enterprise. This also helped in deciding how important each insect pest might be to their overall farming systems.

The questionnaire was divided into 4 parts. Part 1 dealt with their farm details, Part 2 on insect identification, Part 3 on management decisions and Part 4 on future possibilities. The responses were low in the number of completed questionnaires returned, but the data that was received was used to show the benchmarks for the capsicum and eggplant growers in each of these 4 areas at that time.

A second questionnaire was to be sent out at the completion of this project, to provide a measure on how the IPM strategies were being adopted. Due to the poor response to the first questionnaire and lateness in the publication of the Insect Pest Guide this was not undertaken.

~~MATERIALS and METHODS~~

~~This questionnaire with a covering letter was posted to capsicum and eggplant growers in the different vegetable growing regions in January 2001. The regions included Western Australia, Granite Belt, Lockyer Valley, Gympie, Bundaberg, Bowen, Gumlu and Burdekin. Names were obtained from grower lists at centres within the survey regions or through the Industry Development Officer in the Western Australia. The growers were asked to respond to the questions for their own farming enterprise and return the sheets to us. A stamped self-addressed envelope was included for growers to return the questionnaire.~~

~~With no replies from the Western Australia region, this questionnaire was resent in October of that year. There were no replies from that area to this second request, so no further requests were made.~~

~~In evaluating some of the results from the questionnaire where growers were asked to prioritise their response, a formula was used to help in determining the priority order. Where this has been used a note on the method is included with the results.~~

~~RESULTS~~

~~Part 1. Farm Details.~~

~~Sections 1 - 4~~

~~The number of questionnaires posted out and the number returned from all districts are given in Table 1. There was a low overall response with an average of 22%~~

- ~~"On our farm the use of crop consultants has been discontinued because of the fear of contaminating our crops from other areas. I don't believe that thorough decontamination is 100% effective".~~
- ~~"My present system using a combination of hard and soft chemicals with the assistance of a few naturally occurring predators just does not work. I am at a loss as to how to achieve an acceptable pest population".~~
- ~~"My particular situation is that I need more skills at crop monitoring, but the time available to learn these skills is scarce. Also the possible up front costs of learning can be a problem. In the long term up front costs would not count".~~
- ~~"Any assistance is gratefully accepted. We hope that this survey leads to further education in this field. At last something constructive is beginning to happen".~~
- ~~"Field days and demonstration days depend upon timing. During the busy part of the season, time away from the farm needs to be kept at a minimum".~~

DISCUSSION

The number of questionnaires sent out would have been adequate to get the base line data required on the insect control methods being employed by capsicum and eggplant growers throughout the different growing regions. The fact that only 22% were returned has meant that some of the results may not be fully representative of the insect management practices being employed. The reason to split the replies into regions was to show the differences between the insect pests and their importance for these regions. The need to separate some of the replies from capsicum or eggplant growers was necessary to see the differences in the insect pests and the management of these pests.

There was 100% agreement that growers saw Integrated Pest Management (IPM) as important to their farming system for a number of reasons and these reasons were similar for all regions. This reinforced the need for the development of IPM systems in capsicum and eggplant crops and the replies to the questionnaire did not necessitate any changes in direction of the original project.

In the project proposal, a number of insects were listed as major or minor pests of the two target crops. From the responses in the questionnaire, the insects listed matched those that were listed in the project proposal with only some additional insects listed as pests in particular regions. Fruit flies were listed as mainly a quarantine problem, but in the South and South East regions these insects are regarded as production problems. Mites were originally considered minor pests but the responses indicated that they are major pests.

Before IPM systems can be implemented it is paramount that the insects found in a crop can be identified. The responses to the questionnaire suggested a lack of knowledge or experience in this regard. The publication of the book to assist growers with insect identification will be very important in the development of the IPM systems in vegetable crops. Growers have indicated a willingness to undertake scouting of their crops, with some involvement of crop consultants.

CAPSICUM

INTRODUCTION

Developing IPM systems requires information on the individual insect species to be known. Heliothis and aphids are the main insect pests of capsicum crops. The Biology and Ecology of Heliothis has been summarised by Zalucki *et. al.* (1986), the damage, action level and controls for aphids are given by Brough *et.al.* (1994). The control of these pests by beneficial insects is the focus of this project. These beneficial organisms are commercially available as listed in the Good Bug Book.

Previous research in capsicum crops in the dry tropics had established that there are a number of beneficial insects that control Heliothis and aphids (Brown 2000). These include a number of species of ladybird beetles, green and brown lacewings, spiders, predatory bugs and parasites of aphids and Heliothis. Current controls for the insect pests rely on insecticides, and evaluating the effects of these insecticides on those pests and the beneficial insect populations is given in **sections 1(a) and 1(b)**.

Thrips have caused up to 80% loss of production by transmitting Tosporvirus and western flower thrips (WFT) are major vectors of these viruses. This thrips species has been positively identified in the dry tropics region (Medhurst[1] 2002).

Management of WFT in the field is reliant on frequent insecticide use in a rotation program (Medhurst[2] 2002). These insecticides exhibit broad activity across many insect species and do not fit into IPM systems.

Researchers in America have found that relying on insecticides for control of WFT, their usefulness is limited and that two biological control agents, minute pirate bug and big-eyed bug are proving successful in controlling field populations of WFT (Broughton 2002). These two predatory bugs are present in Australia.

In glasshouse production systems, a predatory mite, *Typhlodromips montodorensis,* is being tested to control WFT (Steiner *et. al.* 2002). This predatory mite is native to the dry tropics region (Steiner per com).

Physical barriers are used in IPM systems and netting was evaluated as a physical barrier in this project.

Evaluations on the method of introducing the predatory mites into the crop and the effectiveness of netting against thrips and other insects is given in **sections 2 (a) and 2 (b).**

Studies evaluating insecticides to control aphids, [Kay and Brown, 1989] a sampling method based on counting the number of insects per leaf on a number of plants was used. In assessing results using this sampling method, some concern emerged as to whether all insects were being detected. To verify this, whole plants were collected and insect presence noted for each part of the plant. The results are given in **section 3.**

Growers have concerns that the results from small trials, on the relationship of the pest and the beneficial insects that are associated with them, are not applicable in commercial crops.

To assist with the adoption of IPM by growers, crop monitoring was undertaken on grower properties during the study. One of the reasons was to gain an understanding of the interaction of the insect pests and the beneficial insects in large areas of capsicum crops and the second to show that IPM can be practiced in these commercial crops. The outcomes from these studies are given in **section 4**.

To assist in monitoring, Heliothis pheromone traps were set up throughout the dry tropics growing regions to monitor Heliothis activity.

MATERIALS & METHODS

~~In the following sections, when reference is made to a block of capsicum, each block is 10 beds wide by 60 metres long, established on black plastic mulch with each bed containing 2 rows of plants staggered at 55cm spacings. The crops were irrigated through T tape and a pre-planting application of a complete fertiliser was applied prior to laying the mulch. Fungicides were applied weekly.~~

~~In evaluating the insect populations, 5 or more randomly selected plants were tagged. On each of these tagged plants, 5 randomly selected leaves were inspected and the insect numbers noted. The same leaves were not selected, but it is possible some were counted more than once during the period of a trial. All insect stages, egg, larvae/nymph and adults were recorded.~~

~~Where variations occurred to these methods listed above they will be outlined under each section.~~

~~Section 1 (a) - Evaluation of insecticides on pest and beneficial insect populations.~~

~~In a block of capsicum, plots were a single bed, 5 metres long and separated by 1 guard row between beds and 2 metres along each row.~~

~~The insect pests were allowed to increase so that the beneficial insect numbers could build up prior to insecticides being applied.~~

~~Five chemicals and 1 unsprayed treatment were evaluated. Treatments were replicated 5 times in a randomised block design. All sprayed treatments were applied in water at the rate of 1000L/ha through a motorised knapsack sprayer.~~

~~The following treatments and rate of application were:~~

~~A.~~	~~XenTari WG~~	~~Bacillus thuringiensis subsp. Aizawai.~~	~~at~~	~~2kg /ha.~~
~~B.~~	~~Success~~	~~120g/L Spinosad~~	~~at~~	~~400ml /ha~~
~~C.~~	~~Nudrin~~	~~225g/L Methomyl~~	~~at~~	~~2L/ha~~
~~D.~~	~~Novaluron~~	~~100g/L Rimon~~	~~at~~	~~750ml /ha~~
~~E.~~	~~Emamectin~~	~~44g/kg Proclaim~~	~~at~~	~~250g/ha~~
~~F.~~	~~Control – Nil spray.~~			

Some parasite activity was recorded between the 18th and 25th August but aphids were not detected during sampling in the following week.

Table 53. Average number per plant of the beneficial insects recorded on plants at 2 sites.

Date	Ladybird Beetles		Lacewings		Aphid parasites		Spiders	
	Gumlu	ARS	Gumlu	ARS	Gumlu	ARS	Gumlu	ARS
21/7								
28/7			0.02	0.04				
4/8		0.24		0.64				
12/8		0.04		1.0			0.04	0.04
18/8		0.2		1.24	0.1			
25/8		0.12		1.68	0.8		0.12	0.12
1/9		0.08		1.24	0.38		0.28	0.28
8/9				0.75			0.16	1.16
15/9								

Table 53 shows the difference in the number of ladybird beetles and lacewings between a commercial farming region where insecticide use is high compared to the research site where minimal insecticides were used.

DISCUSSION

Section 1 (a) - Evaluation of insecticides on pest and beneficial insect populations.

Results from this trial reinforce the findings of previous studies that showed the effectiveness of beneficial insects in controlling aphid populations in capsicum crops (Brown 2000). Not only are they very effective in controlling aphids but also they do this in a very short period of time. The data showed that an average population of 0.05 ladybird beetles and 0.07 mummies (parasitised aphids) per leaf reduced an aphid population from 5.9 to 0.38 per leaf within 7 days. This reduced a damaging population of aphids to a population of minor importance.

It's interesting to note that following the one spray application, aphid populations increased. This higher number of aphids in sprayed crops is seen in section 1 (b) as well. This could be the insecticides effect on the beneficial insects but their numbers were too low and did not show any significant difference between the treatments. Following control by beneficial insects a second time, the aphid population did not increase when no more sprays were applied.

The effect of one insecticide spray to control Heliothis on the beneficial insects is not conclusive as the beneficial insect populations were probably decreasing due to the low number of their hosts being available as food. However the insecticides did reduce spider numbers.

Heliothis moth counts taken from the pheromone traps were low and could indicate that the Heliothis populations would be low in this crop. From Sequeira (2004) where he studied the recruitment and loss of juvenile stages of Helicoverpa spp. he showed the percentage loss of eggs on plants varied from 80% to 84%. The survival of eggs can be low and the reason for low survival cannot be partitioned to any one cause. It has also been shown that low egg numbers can have a high percentage of larvae survive.

The level of damaged fruit recorded from the 3 harvests, indicated that even with this very low population of Heliothis we had up to 8% damage in the second harvest with an average of 4% overall damage in the unsprayed blocks. Growers have indicated through discussions with them that they will tolerate up to 10% damage if there is a reduction in chemical use. Based on the growers' acceptance of 10% damage and with an average of 9 fruit per plant being harvested from this trial, indicates that the loss of one fruit per plant is the maximum they will accept.

Section 1 (b) - Comparisons between a sprayed and an unsprayed crop on insect populations.
Significantly more fruit was harvested from the unsprayed block than the sprayed block. Agronomic practices were similar except for the applications of insecticides.

From previous trials, the number of aphids recorded per plant should not have contributed to this difference in fruit numbers. The main pest of capsicum is Heliothis and prior to sprays being applied (19^{th} July), the percentage of fruit damaged was 3.15% and 6.42% respectively for blocks A & B. This is approximately a 50% difference. Following the first spray application the percentage of fruit damaged dropped to 0.8% & 4.17% respectively for blocks A & B, a difference of 5 times. This difference is the only time it varied from approximately 50% between the sprayed and unsprayed blocks. Whether this difference is due to insecticides or was due to other factors is unknown.

The number of Heliothis eggs recorded increased during July and this corresponded to the period of high moth trap catches. Predation by the beneficial insects could have been the reason for no larvae being detected. This supports the reasons to develop IPM systems.

Because the aphid population remained low in both the sprayed and unsprayed blocks, no differences could be measured. With both blocks having low aphid populations, the beneficial insect populations were also low. The ratio of beneficial insects to aphid numbers is high enough to stop aphid populations developing.

Beneficial insect numbers were higher in the sprayed block compared to the unsprayed block and this is because the aphid numbers were also higher. This demonstrates that aphids need to be present before beneficial insects numbers increase.

Section 2 (a) - Evaluation of predatory mites on thrips and netting as a physical barrier to pests.
The netting was placed over this crop when the plants were first transplanted out into the field. As the plants grew the netting became tight across the top of the plants and with wind blowing across the site and this caused rubbing and breaking of the growing tips of the plants. As these tips dried out they became hard and tore the netting. This exposed the plants and no further evaluations could be made on these treatments.

Future trials will need to allow more slack in the netting when setting it up over the plants so that the netting can expand as the plants grow to avoid damage to both the plants and netting.

It was thought that the mites would not survive on the seedlings prior to planting. The first experiments undertaken with this mite have been in glasshouses. The seedlings were planted out on the 3rd October and it was not until 4 weeks later that the mites started to increase in numbers.

Future trials were to look at introducing the mites onto the plants in the field as this could reduce some loss in mite numbers from shaking the plants when transplanting them into the field.

Section 2 (b) - Evaluation of predatory mites on thrips.
The thrips species in this trial was identified as *Frankliniella sp.* (tentatively identified as *F. williamsi*), which is a species that can be confused with WFT. This species and other thrips transmit Tosporvirus . It has been reported that *T. montdorensis* will feed on a number of different species of thrips (Stiener per. Com.), which make it an ideal biological agent to include in any IPM system.

This predatory mite occurs naturally in the dry tropics and this has been confirmed by collections taken by the Marilyn Steiner and myself. These were made from capsicum and weeds in the Burdekin region. Introduction of beneficial insects from areas where the climate may be different may have caused some introductions to fail, but if they already occur in that region then they have a very good chance of establishing if encouraged.

With sampling crops in the field using the sub-sampling method, there is a tendency to subconsciously select leaves in the top 2/3rd of mature plants even though the leaves are randomly selected. This area has the highest number of Heliothis eggs and indicates that this is the ideal area to scout to determine Heliothis egg numbers.

Flowering crops are more attractive to Heliothis moths as the adults use the flowers as a food source. It was anticipated that Heliothis moth activity would increase during this reproductive period of the plant.

Further trials on the introduction of predatory mites were not undertaken in this project as this is being evaluated in another project developing WFT control. Results from that work will be included in the development of IPM systems in capsicum and eggplant crops as research findings are made.

Section 3 - Structure of capsicum plants and sampling techniques.
This trial identified the four sections of the capsicum plant where the insects can be found. Some of this knowledge is new and now more emphasis can be given to those sections where it will be advantageous to detect the different insect species by this sub-sampling method.

The information on where insects can be found in capsicum crops also has important implications in developing a reliable sampling method. Sampling methods need to be effective in having the capacity to detect all insects in the crop and in some insect species, the different life stages. This is especially so when developing IPM systems that are relying on biological interactions for control of the pest species.

The method of randomly selecting plants throughout a crop and then examining 5 randomly selected leaves on each of those plants has proven to be effective. The information gained in this trial does not give the number of plants that need to be examined in a crop but the method has been shown to be effective in detecting all major pest species, over 90% of the minor pests and beneficial insects as compared to sampling the whole plant. This sub-sampling method has the capacity to detect the different life stages of the insects that are used to indicate population numbers.

When scouting for aphids by this sub-sampling method, it will detect populations on all sections of the plant when it is small but as the plant grows there is a tendency to take samples from the top and middle sections of the plant. From the results of this whole plant sampling it is possible that the numbers recorded from inspecting more leaves in the middle section of the plant could underestimate of the real population.

The results showed that if Heliothis egg numbers are below an average of 1 per plant, very few larvae will be present in the crop and only when the egg numbers rise above 1 per plant are larvae found. They also showed that Heliothis moth activity does not increase during the reproductive period of the capsicum plants.

Sampling for thrips should be undertaken by checking in the flowers and not by using the sub-sampling method. Why thrips populations decreased in this trial is unknown, but it could be possible that predatory mites were present. Sampling was not undertaken for them.

The information above is based on low to moderate insect populations and sampling in crops with high insect numbers may need some modifications.

When sampling insect populations in crops there is a prerequisite that the insects can be identified. Not only do the pest species need to be known but also the beneficial groups and non-pest species. Applying insecticides is costly and applying controls purely on insect numbers is flawed. The costs include the product, the application time and cost of equipment and also the effect on the environment. Identification of the insect groups is required prior to adopting any IPM system.

With the availability of a book “INSECT PEST GUIDE: a guide to identifying vegetable insect pests and their natural enemies in the dry tropics”, growers and other crop consultants are now in a better position to scout crops with confidence in that most of the insect groups will be detected.

Section 4 - Results from sampling on grower properties.

Monitoring in commercial crops was to help in the adoption of IPM by growers but some delays were experienced through crops being sprayed.

Trials showed the effectiveness of beneficial insects. In one trial aphid parasites controlled aphid populations within a week from the first detection of mummies (parasitised aphids). This trial had one insecticide applied for aphid control, though it was not needed. Fruit harvested from this crop was acceptable to the grower not only from the good fruit yields but also from very low cost inputs to control insects. Normally this crop would have received between 7 to 10 insecticide sprays as recommended to him for some of the other blocks.

Aphid numbers were again seen to increase in some of the sprayed crops with beneficial insect numbers also increasing.   Beneficial insect numbers only increase when pest species are present as the beneficial insects rely on them for food.

Heliothis egg counts can be misleading.   In some of the trials where low populations were detected an average of 1 egg per plant was needed before larvae were detected. Some of the fruit damaged reached 8%.   In another crop the egg numbers were very high and this ratio increased to a high of 38 eggs per plant before a larva was detected. With these high egg counts it was anticipated that larval numbers would have been high and more fruit would have been damaged.   Differences in the number of fruit harvested between this crop that had low numbers of sprays applied, compared to a heavily sprayed crop, showed very little differences.   Whether growers are prepared to accept slight losses in return for savings by less chemical usage will need to be considered by them.

The importance of cluster caterpillar causing indirect damage by chewing large holes in the plant canopy and allowing the fruit to be sunburnt has to be considered in the control program.   They are minor pests and cause direct damage by feeding on the fruit.   They contributed to some of the fruit loss in one of the trials.

The difference between regions where high insecticide usage has been used for many years compared to sites with low insecticide use shows the difference in the beneficial insect activity.   These beneficial insects need host insects to survive and by keeping pest populations low, as in the high insecticide usage region, these beneficial insects cannot survive.   With the adoption of monitoring crops and then deciding if pesticides are needed will see a reduction in insecticide use.   This will benefit the beneficial insects and will see them return to effective numbers.

EGGPLANT

INTRODUCTION

Development of IPM systems in eggplant depended on the control of silverleaf whitefly (SLWF) by parasites. The evaluation and release of parasites was to have been completed by the commencement of this project but had not occurred. With parasites not being available the evaluations of softer type pesticides were undertaken for SLWF as well as for controlling the other insect pests. Many of these other insect pests species are the same as those found in capsicum crops and are influenced by the same beneficial insects. No recent reports on the evaluation of insecticides to control eggfruit caterpillar, a serious pest in eggplant, were found.

Trials evaluating biological and broad-spectrum insecticides against eggfruit caterpillar, Heliothis, aphids, thrips and SLWF are reported on in **section 1**.

In developing controls for eggfruit caterpillar, an understanding of the biology and the ecology within the crop was needed as little information is published on this insect or its habits in eggplant crops. This insect is one of the main pests of this crop and information that could assist in controlling it would be useful. Previous studies (Brown 2002) identified the sex attracting pheromones of this insect and allowed artificial pheromones to be developed to monitor the male moth flights. The contribution from those studies and from studies within this project through field observations and laboratory studies have identified the eggs of the eggfruit caterpillar. No records on the description of the eggs could be found in the literature. Having the knowledge to identify these eggs has allowed further studies to be undertaken. The outcomes of these are given in **section 2**.

To support the outcomes from small research trials, on farm monitoring was undertaken. Information gained under section 2 assisted in the improvement of monitoring of insect pests in commercial crops. Information gained from commercial crops highlighted the problems that needed to be solved prior to an IPM system being developed. The results presented in **section 3** are observations from commercial crops.

~~MATERIALS & METHODS~~

~~Reference to a block of eggplant in this report means that each block was 10 beds wide by 60 metres long, established on black plastic and trickle irrigated through T tape. A pre-planting application of a complete fertiliser was applied prior to laying the mulch.~~

~~Evaluation of treatments for SLWF, were made by randomly selecting a number of leaves per plot and counting the number of honeydew drops produced by SLWF within two days. Honeydew drops were recorded by placing the leaf in a zip lock plastic bag with the top of the leaf placed on paper towel to reduce condensation. These were then placed on a bench with the underside of the leaf facing down. Counts were made of the honeydew drops formed on the plastic.~~

~~Counts of eggfruit caterpillar eggs were made and the position on the fruit and fruit stem where they were laid recorded. The positions were:~~

~~a. On the fruit stem that was approximately 4 to 6cm long.~~

~~Table 68. Percent parasitism of Heliothis eggs on eggplant.~~

~~Date~~	~~Location~~	~~% larvae emerged~~	~~% parasitism~~	~~% Dead~~
~~22/5~~	~~Mt. Kelly~~	~~100~~	~~0~~	~~0~~
~~23/5~~	~~Mt. Kelly~~	~~100~~	~~0~~	~~0~~
~~15/7~~	~~ARS~~	~~94~~	~~6~~	~~0~~
~~25/7~~	~~ARS~~	~~56~~	~~6~~	~~38~~
~~2/8~~	~~ARS~~	~~82~~	~~2~~	~~16~~

~~Table 68 shows that the Heliothis egg parasites are active in eggplant crops. The percent parasitised is low compared to other collections where up to 70% of the eggs can be parasitised.~~

DISCUSSION

Monitoring of eggplant crops can be difficult. When crops are young, leaf sampling is sufficient to note insect numbers but in most cases the only major pest at this time is SLWF. If this pest is not controlled early it can increase in numbers rapidly. As crops begin to flower, flower samples should be taken to note thrips populations. In mature crops, it is difficult to sample the plant due to large leaves and the compactness of the plant. Fruit are produced in all sections of the plant, and fruit including the fruit stems should be used to monitor the eggfruit caterpillar and Heliothis populations by egg counts.

In section 1 (a), the difference in numbers of good fruit and also the total fruit harvested between the two Bt treatments in section cannot be explained. Similarly, why the Nitofol treatment produced significantly more fruit but also had significantly more larvae detected in the fruit cannot be explained.

Sampling for thrips is best undertaken by checking the flowers and fruit buds as checking leaves is ineffective. This was also shown to be the best method of determining thrips populations in capsicum. Aphid numbers were not high in these crops. Observations from crops in the regions showed beneficial insects are usually present. The use of Amino-feed did not appear to attract predators to a level where they were comparable to treatments without this additive. This is similar to the results found by Kay *et. al.* 2003. Sanmite did reduce the SLWF populations but not Heliothis or Thrips. Proclaim reduced Heliothis but not SLWF. The current recommendations for SLWF control include some of the new growth inhibitor type pesticides and these should be tested in any future IPM development in eggplant crops. Registration of these products for use on eggplant was not pursued during this project. The experimental sample of the Ark products did not control SLWF populations.

The information gained on eggfruit caterpillar from these studies has enhanced our knowledge and will lead to changes in how we control this pest. It has been shown that the preferred oviposition site of eggfruit caterpillar eggs is in the fruit area with very few eggs being found elsewhere on the plant. Even around the fruit area the most preferred site is on the fruit and especially the fruit tip. Sampling of fruit revealed that approximately 50% of the fruit had eggs laid on them, and 60% of these were single egg lays. Egg numbers per fruit were as high as 13, but 90% of the number of eggs per fruit was between one and three. Larvae burrow into the fruit within a very short period of emerging from the egg. This leaves a very short period to control this pest. It was also shown that one larva can damage the fruit sufficiently to make it unmarketable. No parasites have been recorded from this insect either in the egg or larvae. Future development in controls should use this information.

Pheromone traps developed to attract the male eggfruit caterpillar moths are successful but they should only be used to indicate if eggfruit caterpillar is active in the region. The development of controls through mass mating disruption has been tried in previous studies (Brown 2002).

Attempting to rear eggfruit caterpillar in the laboratory failed. This was due to the slices of fruit breaking down and drowning the very small larvae. Breeding larvae in whole fruit may be possible but this will not allow daily observations to be made to study larval growth.

From collections of fruit with larvae present, a new insect species was identified. The larval stages could not be distinguished from the eggfruit caterpillar larvae but the adults have different wing markings. The insect was identified as *Leucinodes orbonalis* Guenee, from the family Pyralidae.

HELIOTHIS PHEROMONE TRAP - FLIGHT DATA

INTRODUCTION

Heliothis, both *Helicoverpa armigera* and *H. punctigera* are recorded pests of capsicum (Kay *et. al*. 1990). Use of pheromone traps to study the seasonal occurrence and abundance has been documented by a number of researchers. Maelzer *et al* (1996) used long-term light trap and weather data to determine the seasonal population dynamics of *H. punctigera*. Others (Rochester *et al* 1998) have used pheromone trap data along with egg collection information (Kay 1999) to try to explain possible migration of *H. armigera.*

The seasonal pattern of Heliothis has been documented for the Dry Tropics regions for over 7 years and some of these data have been reported on in previous projects (Brown 2000). This current information has been built onto the previous records, and now there is a better understanding of the flight patterns for both of these species is better understood for the dry tropics area.

~~MATERIALS & METHODS~~

~~Both *H. armigera* and *H. punctigera* pheromone traps were placed on properties that grew capsicum or eggplant. The traps were Agrisense green funnel traps charged with Agrisense lures for each species.~~

~~In the Gumlu region, a major capsicum growing district, two sets of traps were set up with one *H. armigera* and one *H. punctigera* being placed on each property. The traps were placed along side crops approximately 1m above ground height. These two sites were approximately 2km apart. The Gumlu area is isolated from all other growing districts by approximately 40km.~~

~~Another set of traps, were set up in the area known as upriver from Home Hill. This site was an isolated vegetable property. Another set was set up within 5 km of this site in an area mainly growing sugar cane but with small areas of small crops.~~

~~In the Mt. Kelly region, a set of traps was placed next to sweetcorn crops but later this area changed to cane. Monitoring was maintained to note the effect of cane on flights and numbers of moths collected.~~

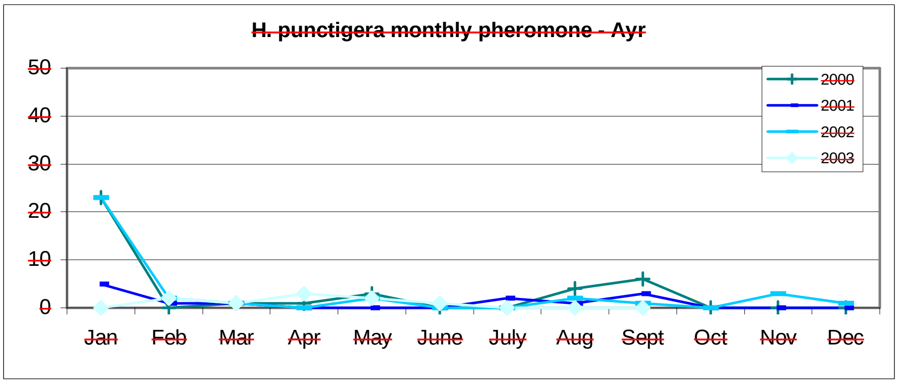
~~In the Ayr region, one set of traps was placed on the Ayr Research Station that has a number of mixed crops and in the Brandon region another set of traps was established. The Brandon area is very isolated from other vegetable cropping areas and is surrounded by native grasses and cane.~~

~~Traps were serviced weekly and lures replaced 6 weekly. To kill the moths lured into the traps, a 3cm^2 cut from Shelltox Ministrips was placed inside each trap.~~

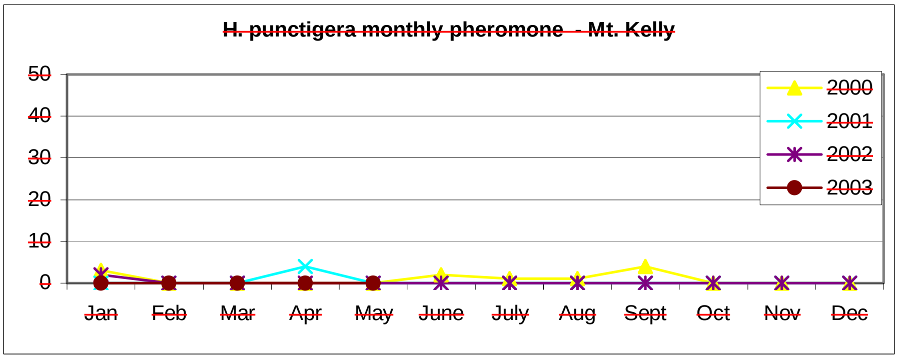
~~RESULTS~~

~~Figures 33 to 38 show the trapping data for *H. armigera* from six sites. The data covers the years 2000 to 2003.~~

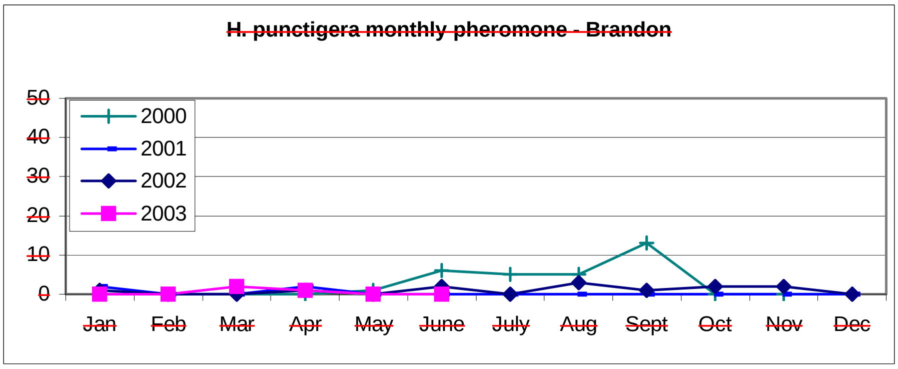
~~**Figure 42. Total number per month at Ayr.**~~



~~**Figure 43. Total number per month at Mt. Kelly.**~~



~~**Figure 44. Total number per month at Brandon.**~~



DISCUSSIONS

Helicoverpa armigera and *H. punctigera* are pests in capsicum and eggplant crops, with *H. armigera* the major species occurring in the dry tropics. *H. armigera* is present all year during the cropping period between February and November. *H. punctigera* tends to be found between the months of July and October and seldom are the main pest species that inflicts economic damage to the crops.

The variation between the trapping regions supports the theory that there is little migration of moths, but this may occur at the start of the season. After the initial invasion, the moth numbers collected is a reflection of the insect activities in crops on individual properties. Some of the variations in numbers trapped could be due to farming practices and some could be caused by not finding suitable hosts. This is especially so in the Burdekin where there is extensive cane fields between vegetable crops. All sites in these areas have low populations.

Numbers of Heliothis collected in the Gumlu region are approximately twice as high as the next site in Home Hill. Even between the two Gumlu sites numbers are different, supporting the reasoning that the populations are localised.

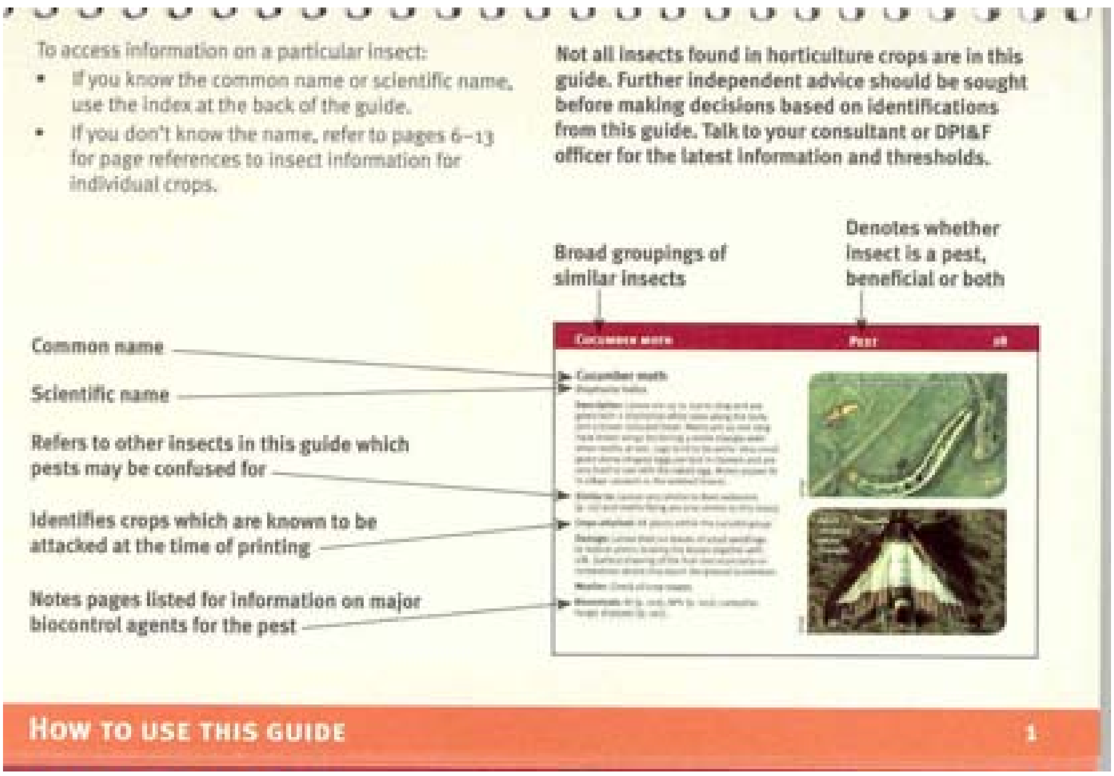
Sampling fields for eggs and monitoring pheromone traps show there is not a strong link between the numbers of moths trapped and egg counts. Growers should not rely on pheromone traps to base their control actions on, but traps do serve the purpose of indicating moth activity. Sampling within the crop is still strongly recommended.

TECHNOLOGY TRANSFER

The production and publication of a book "INSECT IDENTIFICATION GUIDE a guide to identifying vegetable insect pests and their natural enemies in the dry tropics" is the most important and most valuable outcome from this project. Without this guide growers were not in a position to adopt IPM systems unless they had training in pest identification. This book designed for growers and crop consultants is very comprehensive.

The contents with page numbers include:

A copy of the How to use this guide is listed below.



The crop pests listed include other crops beside capsicum and eggplant. It was considered important by me that if a book was to be published it should cover most of the tropical vegetable crops. This will aid producers across regions and encourage the monitoring of crops. The identification of the insects seen in the crop will be possible with the aid of this book. A reduction in the indiscriminate use of insecticides should occur, as all insects will not be seen as pests. It may also lead to an increase in beneficial insect activity in crops.

The book has been design to withstand robust handling and for the user to take into the field. Insects found in the crop can be identified immediately saving the need to collect and identify them later.

Colour photographs of all the insect pests are given along with their name and scientific name, descriptions of the insect and its immature stages, insects that they could be confused with, crops attacked, damage caused, monitoring tips and bio-controls. With the beneficial insects similar information is given with the pests attacked replacing the crops attacked and impact on pests replacing the bio-controls.

This book has been made available to growers and crop consultants in Ayr, Bowen and Bundaberg. Agricultural suppliers who do consultations for growers have also been supplied copies to use and distribute. Many requests for copies have been received following a reference to it in the Good Fruit and Vegetable newsletter. Some have been from interstate and all have been sent copies. Requests from schools undertaking education in agriculture have also been received with copies sent for inclusion in their libraries.

Comments received have all been complimentary with the common theme that this type of book has long been overdue. A copy of this book has been put on file with this report.

Other information has been made available to growers during the duration of the project. These include:

1. A talk presented at the Entomology conference in 2001. The presentation outlined the work to be undertaken in this IPM project.

2. A presentation was given to growers and crop consultants in Bundaberg in 2002. This was part of a “Capsicum Information Session” extension activity. Discussions were held with growers and other researchers on the information presented.

3. A seminar was attended in Gumlu during 2002. At this seminar the outcomes achieved up to this stage were presented.

4. Presentations were given growers and crop consultants in Gumlu and Bowen during 2003. This was part of a larger seminar with the theme on “Pest and disease information”. These meetings provided the opportunity to present the value of IPM and outcomes of the project.

5. Grower meetings were attended to provide information on the pests and potential pests in horticultural crops.

6.   A field day was organised on the Ayr Research Station.   This was arranged so that growers could turn up on either of the two days.   Part of the day was to inspect a crop of capsicum grown under IPM.

7.   A second meeting was held in Gumlu in 2004.   This was at the request of crop consultants to give an overview of IPM.   The launch of the IPM book was made at this meeting.

8.   Newsletters were sent to the ABC and local commercial stations.   In some instances the information was sent to the local television stations as well especially on the release of the IPM book.

9.   News release were made throughout the project to keep growers and the public informed of the IPM progress and publication of the Insect Book.

At the start of this project, the extension officer who was part of the research team was going to send faxes out on a monthly basis.   These faxes were to inform growers and others of the activities being undertaken and in co-operation with growers, results from farm trials.   Prior to this person leaving the Department within a few months of the project starting, a few faxes were sent.   With no replacement of this extension officer, these faxes ceased.

RECOMMENDATIONS

Developing IPM systems in crops is a large task and especially so in vegetable crops. With most vegetables the slightest marking on the fruit can make it unacceptable for the market. Integrated Pest Management systems have been developed in vegetables but their adoption is sometimes slow due to a number of factors. The price received for a commodity is a major factor. In times of high prices chemical costs are not important in the economic equation but as the price of produce falls, the costs of chemicals becomes important and this is when IPM will start to be adopted.

Integrated Pest Management systems appear complex but aren't, mostly relying on crop monitoring to gauge insect numbers and adoption of good farming techniques. These include; having crop breaks, weed control, destruction of old crop residues and use of specific insecticides i.e. biological types for Heliothis. With the aid of the insect identification book no one should be disadvantaged in undertaking crop monitoring as the old problem of not being able to distinguish insect pests from non-insect pests is removed. This has been the major stumbling block in the adoption of IPM.

Recommendations from this project include:

1. That all growers should get a copy of the INSECT PEST GUIDE - a guide to identifying vegetable pests and their natural enemies in the dry tropics.

2. A new project should be developed. Titled "Integrated Pest Management – Phase 2". Integrated Pest Management is an on going process and should not be lost with the incursion of new pests. This second phase of the project should encompass the following:
   - A series of information seminars should be given in all of the capsicum and eggplant growing regions to demonstrate the use of the INSECT PEST GUIDE in these crops. This publication was not available during the project and is seen as the most important tool in helping growers adopt IPM systems.
   - Evaluate utilising the new imported parasites for Silverleaf whitefly. This insect pest is the main reason for IPM not succeeding in eggplant.
   - During this project, Western Flower Thrips were detected in the dry tropics for the first time. There is a need to undertake research into developing new controls of this pest, as the current recommendations do not fit IPM systems. Initial work started to evaluate predatory mites that are native to this area and this needs to be explored further in the control of thrips.
   - Spiralling Whitefly has reached the Burdekin, one of the main capsicum and eggplant growing regions. Current recommendations to control this pest rely on parasites. Their effectiveness is questionable.

ACKNOWLEDGEMENTS

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- To the staff of the QDPI&F publishing services who offered assistance in the design of the insect guide.