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

John Brown
QLD Department of Primary Industries and Fisheries

Project Number: VG00026

VG00026

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Know-how for Horticulture™

Queensland **the Smart State**

Project Number VG00026

(31st October 2004)

Developing and Implementing Integrated Pest Management Systems for Eggplant and Capsicum.

J. D. Brown

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Queensland Government
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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%

replying. The best response from any farming district where more than 1 grower replied was 33% from Gumlu. To indicate differences between similar growing districts, the responses from the districts have been grouped into three regions. The Dry Tropics region includes the growing districts of the Burdekin, the Gumlu and the Bowen areas, the South East Queensland Region includes the Bundaberg and Gympie growing districts and the South Queensland region includes the Lockyer Valley and Stanthorpe growing districts. Within these regions the best response was from the Dry Tropics 27%, followed by South East Queensland with 23% and South Queensland with 12%.

Table 1. Number of questionnaires returned from growers in the different growing regions.

	Dry Tropics region			SE Qld		South Qld.		Total
Comments	**Burdekin**	**Gumlu**	**Bowen**	**Bundaberg**	**Gympie**	**Lockyer Valley**	**Granite Belt**	**Total**
Surveys sent out	32	21	17	53*		2	31	**156**
Number returned	8	7	4	10	2	1	3	**35**
Percentage	25%	33%	24%	23%		50%	10%	**Av. 22.4%**
Not growing capsicum or eggplant	0	0	3	2	0	0	0	**5**

* This included growers from the Gympie district as well.

Table 1 shows that 35 responses were received, but 5 of these growers were not growing capsicum or eggplant crops. Their replies have not been included in the following results.

In Table 2, the number of growers in each district has been divided into 6 categories based on the importance of the crop or crops grown to that enterprise. In the second part of Table 2, the numbers indicate the importance of capsicum and eggplant to one another as the main crop grown.

Table 2. Number of growers involved in growing capsicum or eggplant.

Category	**Dry Tropics region**			**SE Qld**		**South Qld.**		**Total**
Crop grown in each farming enterprise.	**Burdekin**	**Gumlu**	**Bowen**	**Bundaberg**	**Gympie**	**Lockyer Valley**	**Granite Belt**	**Total**
Capsicum only			1	1				2
Eggplant only	2							2
Capsicum & eggplant	1			1				2
Capsicum & other		4		3	1	1	2	11
Eggplant & other	4			1			1	6
Both & other	1	3		2	1			7
As the main crop based on Capsicum and Eggplant								
Capsicum		6	1	4	1	1	2	15
Eggplant	7			3			1	11
Both	1	1		1	1			4

Table 2 shows that most capsicum and eggplant crops grown are not the only farming enterprise. There are 2 growers growing capsicum and 2 growing eggplant alone, with 2 growing both of these crops. All of the other growers grow these crops in combination with other crops. Of those who grow capsicum or eggplant, capsicum was the more important crop.

The numbers in Table 2 also show that the Burdekin district grows more eggplant than the Gumlu district and the reverse for capsicum. The Bundaberg district has near equal number of growers growing capsicum or eggplant. These 2 regions had the most responses.

Section 5
In these questions, growers were asked if they saw integrated pest management (IPM) as important in their management of insects. Growers were given a yes/no box to tick and the results are given in the first part of Table 3.

In the second part of Table 3, the number reflects the frequency with which each part of the options within the question, were ticked. Some growers did not score their response in order of priority and the number indicates a total for each time one of the options was ticked.

In evaluating the importance of each of these options, the order of priority given by growers was weighted and the results are given in the bottom part of Table 3. The number 1 priority was given a value of 5, the number 2 priority a value of 4 and so on until the 5th order of priority, which was valued at 1. Other reasons are listed at the end of the table. If the reasons were not prioritised then they did not score in this part of the table.

Table 3. Importance of IPM and for what reason across the growing regions.

	Dry Tropics region			**SE Qld**		**South Qld.**		**Total**
Importance Of IPM	**Burdekin**	**Gumlu**	**Bowen**	**Bundaberg**	**Gympie**	**Lockyer Valley**	**Granite Belt**	**Total**
Yes	8	7		8	2	1	2	28
No			1				1	2
Percentage yes	100%	100%	0%	100%	100%	100%	67%	Av. 93%
The number of times each main reason was #1 in importance								
Environmental	3	3		2	2			10
Market				2	1		3	6
Health	6	3		3	1			13
Costs	3			4	1	1		9
Other					1			1
Weighted scores with # 1 being given a score of 5 and least importance a score of 1.								
Environmental	32	23		22	10	3	4	94
Market	14	15		19	5	4	19	76
Health	38	27		27	5	2	4	103
Costs	29	18		24	5	5	4	85
Other	7	7		8^	5+	1		28

+ = Less chemicals available and clean & green image ^ = Need to break resistance build up

The results given in Table 3 indicate that the majority of growers believed that IPM is important in their farming practices (93%). The reasons were all of those listed in the questionnaire with 2 more included under “Other” option. The most important reasons given for the advantage of IPM were; health, environment and costs. These priorities were reflected across most regions, although the Granite Belt indicated that markets were the most important reason.

Other reasons given for the advantage of IPM were; resistance management, fewer chemicals available and the need to conserve those presently in use, and for a clean and green image for their produce.

Part 2. Insect Identification

Section 1. Pest identification.

In this part of the questionnaire growers were asked to identify their major and minor pests and if they had any problems in controlling any of them. It also asked growers to identify beneficial insects and how they might be useful in their crops. To help growers answer these questions, the questionnaire provided a list of insects as an appendix. This list included known pests, beneficial insects and others not related to the crops. This was to gauge the extent of grower’s knowledge in identifying the different insects as well as to determine the main insects growers found in their crops. It also helped to ascertain whether growers could determine the difference between pests and beneficial insects. The questions also allowed growers to list those insects that they encountered, even if they were not on the list.

The questionnaire asked for the pest insects to be ranked in order of importance. To evaluate this, the number 1 priority was given a ranking of 10 and so on down to 1. If more than 10 insects were listed, those at 10 and below all registered a value of 1. The number of times each insect was identified as a pest is given in Table 4, followed by the average ranking based on the order of importance the growers listed them in. To help establish patterns between capsicum and eggplant growers, the identification of the insects in each crop have been separated and reported on under each crop. No grower responses were received from the South Queensland region for growing capsicum only.

Table 4. Number of times each pest was recorded as a main pest of capsicum in the different regions and their average ranking as per the order of importance.

Insect	Capsicum only						Capsicum & other crop					
	Dry Tropics		SE Qld		S Qld		Dry Tropics		SE Qld		S Qld	
	#	Av. ranking	#	Av. ranking	#	Av. ranking	#	Av. ranking	#	Av. ranking	#	Av. ranking
<u>ACARINA</u>												
<u>Broad mite</u>			1	9								
Mites							5	7	7	8.71	1	9
Russet mite									2	8		
ORTHOPTERA												
Crickets							2	7				
HEMIPTERA												
Aphids	1	8	1	8			8	8.88	7	7.29	3	8.67
Green Vegetable Bug	1	9					1	5	1	6		
Silverleaf Whitefly			1	6			1	10	2	6		
THYSANOPTERA												
Thrips	1	6					5	8	1	6		
Western flower thrips											1	6
Melon thrips											1	5
COLEOPTERA												
Wireworm							3	7.33				
DIPTERA												
Atherigona	1	7					1	2				
Fruit flies			1	7					4	7.5	3	8.33
LEPIDOPTERA												
Cluster caterpillar							1	6	2	6		
Cutworm							1	6	1	6		
Heliothis	1	10	1	10			8	9.75	8	9.5	3	9.33
Leaf miner									1	9		

For growers who only grow capsicum, the insects Heliothis and aphids are a common problem in both the Dry Tropics and SE Qld regions. Where growers grow capsicum and other crops, these 2 insect groups are still the most common pests although mites also ranked high. Green vegetable bug, silverleaf whitefly, thrips, cluster caterpillar and cutworms are also common pests in the Dry Tropics and South East Queensland regions while fruit flies are more significant in South East and South Queensland regions. The other insect pests recorded by growers appear to be local problems

Table 5 provides a comparison of the minor pests of capsicum crops.

Table 5. Number of times each pest was recorded as a minor pest of capsicum in the different regions and their average ranking as per the order of importance.

Insect	Capsicum only						Capsicum & other crop					
	Dry Tropics		SE Qld		S Qld		Dry Tropics		SE Qld		S Qld	
	#	Av. ranking	#	Av. ranking	#	Av. ranking	#	Av. ranking	#	Av. ranking	#	Av. ranking
ACARINA												
Mites							2	8	1	10	1	9
ORTHOPTERA												
Crickets	1	10	1	10			1	10				
Mole cricket							2	9.5				
HEMIPTERA												
Aphids							1	10	2	10		
Green stink bug							1	9				
Green Vegetable Bug							3	8.67	1	7		
Leaf hoppers									1	8	1	10
Rutherglen bug									1	10		
Silverleaf Whitefly	1	9							1	9		
THYSANOPTERA												
Thrips							1	7	2	8.5		
COLEOPTERA												
Wireworm							1	10				
DIPTERA												
Fruit flies			1	8			3	8	3	8		
LEPIDOPTERA												
Cluster caterpillar			1	9			1	10				
Cutworm							1	6	2	9		
Heliothis							1	10				
Leaf miner							1	7	4	9.5		

Tables 4 and 5 show that there are a total of 21 insect types across 7 insect Orders recorded as major or minor pests of capsicum crops. Of these the most common pests are within the order HEMIPTERA the bugs, followed by LEPIDOPTERA (moths), ACARINA (mites), THYSANOPTERA (thrips), DIPTERA (flies), ORTHOPTERA (crickets) and COLEOPTERA (beetles). From these groups the mites, aphids, fruit flies and Heliothis are common in all regions. Green vegetable bug, silverleaf whitefly, thrips, cluster caterpillar, cutworms and leaf miner are common to both the Dry Tropics and South East Queensland regions with leaf hoppers (jassid) common to both the South East and South Queensland regions.

In Table 6 the main insect pests of eggplant are given. This table shows that of the growers who only grow eggplant the insects, aphids, Heliothis and eggfruit caterpillar are the common pests. The insect groups mites, aphids, silverleaf whitefly, thrips, eggfruit caterpillar, Heliothis and leaf miner are all important pests of eggplant in the Dry Tropics and SE Queensland regions. No insects were listed from the grower who responded to the questionnaire from the South Queensland region and no grower grew eggplant only from the South East and South Queensland regions.

Table 6. Number of times each pest was recorded as a main pest of eggplant in the different regions and their average ranking as per the order of importance.

Insect	Eggplant only						Eggplant & other crop					
	Dry Tropics		SE Qld		S Qld		Dry Tropics		SE Qld		S Qld	
	#	Av. score	#	Av. Score	#	Av. score	#	Av. score	#	Av. score	#	Av. score
ACARINA												
Mites	2	6					3	7	4	8.25		
Russet mite									1	7		
ORTHOPTERA												
Crickets							1	9				
HEMIPTERA												
Aphids	1	10					5	9	1	9		
Silverleaf Whitefly							6	9.83	2	7.5		
THYSANOPTERA												
Thrips	1	9					2	9	2	10		
COLEOPTERA												
Wireworm							1	9				
DIPTERA												
Fruit flies	1	6							1	6		
LEPIDOPTERA												
Eggfruit caterpillar	2	8.5					3	8	3	9		
Heliothis	2	8.5					3	7.67	4	8.75		
Leaf miner	1	5					4	8.25	2	8		
Yellow peach moth	1	3										

In Table 7, the minor insect pests of eggplant crops are given.

Table 7. Number of times each pest was recorded as a minor pest of eggplant in the different regions and their average ranking as per the order of importance.

Insect	Eggplant only						Eggplant & other crop					
	Dry Tropics		SE Qld		S Qld		Dry Tropics		SE Qld		S Qld	
	#	Av. score	#	Av. score	#	Av. score	#	Av. score	#	Av. score	#	Av. score
ACARINA												
Broad mite									1	9		
Mites							2	8.5				
HEMIPTERA												
Aphids	1	10					4	9.5	2	9.5		
Green Vegetable Bug	1	9					2	8	1	8		
Leaf hoppers									1	8		
THYSANOPTERA												
Thrips							2	6				
DIPTERA												
Fruit flies							1	9				
LEPIDOPTERA												
Cluster caterpillar							1	10				
Cutworm							1	10	1	10		
Eggfruit caterpillar							1	8	1	8		
Heliothis							3	8.67	1	10		
Leaf miner							1	9	3	9.33		

Tables 6 and 7 show that there are a total of 17 insect types across 7 insect Orders recorded as major or minor pests of eggplant crops. Of these the most common pests are within the order LEPIDOPTERA the moths, followed by HEMIPTERA (bugs), ACARINA (mites), THYSANOPTERA (thrips), DIPTERA (flies), ORTHOPTERA (crickets) and COLEOPTERA (beetles). From these groups the mites, aphids, green vegetable bug, silverleaf whitefly, thrips, eggfruit caterpillar, Heliothis, leaf miner and cutworm are common in the Dry Tropics and South East Queensland regions.

Section 2
This part of the questionnaire was linked to the previous questions and asked growers to identify the insects that they have trouble in controlling. In Table 8, the insects identified by growers as being difficult to control are given for both capsicum and eggplant.

Table 8. List the insects in either capsicum or eggplant crops that growers have indicated as difficult to control.

Insect	Capsicum			Eggplant		
	Dry Tropics	SE Qld.	South Qld.	Dry Tropics	SE Qld.	South Qld.
ACARINA						
Mites	Yes	Yes		Yes	Yes	
HEMIPTERA						
Aphids	Yes			Yes		
Silverleaf Whitefly	Yes	Yes		Yes	Yes	
Green Vegetable Bug	Yes					
THYSANOPTERA						
Thrips				Yes		
Western Thrips			Yes			
Melon thrips			Yes			
COLEOPTERA						
Wireworms	Yes			Yes		
LEPIDOPTERA						
Cluster caterpillar				Yes		
Eggfruit caterpillar		Yes			Yes	
Heliothis	Yes	Yes			Yes	
Leaf miner		Yes		Yes	Yes	

Table 8 shows that there are 8 insect types across 4 insect Orders in capsicum crops and 9 insect types across 5 insect Orders in eggplant crops that the growers indicated as having trouble in controlling.

Sections 3 - 4.
This part of the questionnaire was included to establish how many growers were confident in recognising beneficial insects and if they could distinguish between predators and parasites. The information sought was to be used to identify what training should be developed for growers of the 2 different crops.

In Table 9, the number of growers who indicated that they could or could not identify beneficial insects is given. The table also includes their responses to being able to distinguish between predators and parasites. For those growers who grew both crops the response are listed in both the capsicum and eggplant sections.

Table 9. Number of growers who indicated they could or could not identify and distinguish between the beneficial insect groups.

Question	Dry Tropics region		SE Qld		South Qld.		Total	
<u>Can recognise beneficial insects</u>	**Capsicum**	**Eggplant**	**Capsicum**	**Eggplant**	**Capsicum**	**Eggplant**	**Capsicum**	**Eggplant**
Yes	2	3	4	1	4			14
No	6	4				1	3	14
Some	2	4	6	4	6	1	1	24
Cannot distinguish between parasites and predators.	9	10	5	4	5	1	3	37
# whom replied yes and were correct	1	1	1		1			4

There were equal numbers of responses from growers indicating that they could or could not identify a beneficial insect. While 24 respondents indicated that they could identify some of the beneficial insects, 37 could not distinguish a parasite from a predatory insect. Of the small number of growers that responded on the questionnaire as to which insects were parasites or predators, only 4 responses were correct.

Sections 5 – 7.
From the responses to the question on how the beneficial insects were introduced into farming systems, the following numbers were given for capsicum and eggplant growers.

(a) "Introduced as a part of a management system implemented by yourself"
- From the Dry Tropics region – 0
- From the SE Queensland region – 4 for capsicum & 3 for eggplant
- From the South Queensland region - 0

(b) "Introduced as a part of a management system implemented by a consultant"
- From the Dry Tropics region – 0
- From the SE Queensland region – 4 for capsicum & 2 for eggplant
- From the South Queensland region - 0

(c) "Always there, occurring naturally"
- From the Dry Tropics region – 5 for capsicum & 7 for eggplant
- From the SE Queensland region – 7 for capsicum & 4 for eggplant
- From the South Queensland region - 2 for capsicum & 1 for eggplant

(d) " Other"
- From the Dry Tropics region – 0
- From the SE Queensland region – 0
- From the South Queensland region - 0

On the questions on reference material, "have reference material" the following responses were recorded for the different regions and crops.

Dry Tropics region – capsicum Yes 4 No 6 eggplant Yes 3 No 8
SE Queensland region - capsicum Yes 2 No 6 eggplant Yes 1 No 3
South Qld. region – capsicum Yes 1 No 3 eggplant Yes 2 No 0

On the question to ascertain interest in attending an Insect Identification Workshop, 100 % of respondents indicated support.

Part 3. Management Decisions

Section 1 – 3.

Three questions were posed to growers in this section. These questions were to establish base line data on what management decisions growers were making to control the insect pests and what monitoring systems were being used.

In Tables 10 and 11 the number of times growers responded on each of the control options is given for the different regions. Table 10 is for capsicum crops and Table 11 for eggplant crops. As well, the frequency of their monitoring is given for each of these control options. If growers marked more than 1 box then each response was recorded in the data. No "Other" responses were received in the questionnaire and the numbers given for Other in this table refer to either a spray schedule without indicating frequency or vice versa.

Table 10. Number of capsicum grower responses to each of the different management decision and their corresponding monitoring methods.

Region	Basis for management decision	Daily	Twice a week	Weekly	Fortnightly	Monthly	Other
Dry Tropics	Routine spray schedule		4	1			
	Monitoring by self	1	5	2			
	Monitoring by consultant		1	1			
	Part of disease program		1				
	Other						1
SE Qld.	Routine spray schedule			1			1
	Monitoring by self	3	2	1	1		
	Monitoring by consultant		1	3	1		
	Part of disease program	2	1				
	Other						
South Qld.	Routine spray schedule		1		1		
	Monitoring by self		1		1		
	Monitoring by consultant		1	1			
	Part of disease program						
	Other						

Table 10 indicates that the majority of the monitoring is undertaken twice a week or weekly and that the management decisions were based on either routine spray schedules or through monitoring undertaken by themselves.

Table 11. Number of eggplant grower responses to each of the different management decision and their corresponding monitoring methods.

Region	Basis for management decision	Daily	Twice a week	Weekly	Fortnightly	Monthly	Other
Dry Tropics	Routine spray schedule		2	1			
	Monitoring by self	3	4	3			
	Monitoring by consultant	1				1	
	Part of disease program	1	1	1			1
	Other						
SE Qld.	Routine spray schedule			1			
	Monitoring by self	1	2	1			
	Monitoring by consultant			3			
	Part of disease program		1				
	Other						
South Qld.	Routine spray schedule		1	1			
	Monitoring by self		1	1			
	Monitoring by consultant						
	Part of disease program		1	1			
	Other						

Table 11 also shows that the majority of the monitoring is undertaken twice a week or weekly but the management decisions tend to be more reliant on monitoring by themselves and less on routine spray schedules.

In response to the question on sharing information on monitoring and scouting systems, all growers except for 1 responded positively to sharing information.

Part 4. Future Possibilities

Sections 1 – 3.

This series of questions were about the future and grower interest in some of the outcomes that this project would develop. It was designed to understand the level at which monitoring systems would be useful, how they would be used and the best method for extending the project outcomes to them.

In Table 12, the responses have been broken into the capsicum and eggplant crops and for each of the growing regions. The data relate the use of a monitoring system to its implementation by growers in their crops. If growers marked more than 1 box, then each response was recorded in the data.

Table 12. Development of insect monitoring systems in capsicum and eggplant crops and the method growers would use in their crops.

Region	Crop	Would use a monitoring system if developed	Self	Crop consultant	Both
Dry Tropics	Capsicum	Yes	7		3
		No			
	Eggplant	Yes	5	1	7
		No			
SE Qld.	Capsicum	Yes	3	2	5
		No			
	Eggplant	Yes		1	4
		No			
South Qld.	Capsicum	Yes	2	1	
		No			
	Eggplant	Yes			1
		No			

Table 12 shows the majority of capsicum growers in the Dry Tropics would use a monitoring system themselves, whereas eggplant growers were divided between doing it themselves and using a consultant. In South East Queensland growers were similarly divided.

From the questionnaire 100% of the responses indicated that they would attend field days or on farm demonstration sites.

Section 4.
This section of the questionnaire was added so that growers could make comments on the questions or on areas not covered by the questions.
The comments were:

- "Learning to be an Entomologist and grow a crop is not easy. We are prepared to work at it, but need easy (ready) access to competent help".
- "We would like to see a book on beneficial insects, pests and their life cycles".
- "More work to be taken with the 'new age' chemicals".
- "If we go soft on heavy chemical usage, Heliothis is a problem. If established, whitefly are very difficult to eradicate. I have a concern about resistance build up in two spotted mites to Vertimec. Currently we can achieve good results in combination with D C Tron".
- "I see IPM as a way to lower production costs, improve pest control methods and as a safe environment for all. I can almost grow eggfruit completely on biological and predatory control of pests except for the eggfruit caterpillar. It and Heliothis remain our stumbling blocks to complete a IPM strategy in capsicum and eggfruit".

- “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.			

A single spray was applied on the 28th September and fruit harvested over 3 picks, 17th & 25th October and 7th November. Fruit was hand picked and examined for Heliothis damage. The number of fruit picked per plant was recorded.

Section 1 (b) - Comparisons between a sprayed and an unsprayed crop on insect populations.
Two blocks of capsicum, each block divided into 5 plots 10 metres long x 2 beds and separated by 2 beds across the block and 2 metres along the row.

Insecticide sprays were applied to the commercial block (A) on a 7 day rotational program starting with Methomyl (Lannate) on the 19th July followed by Methamidophos (Nitofol) then by Methomyl again. Applications ceased after the 12th August. Sprays were applied through a tractor mounted boom sprayer.

To evaluate the insect populations, 10 randomly selected plants within block A and 15 randomly selected plants in block B were inspected. Five randomly selected leaves per plant were inspected.

Harvesting of the fruit was undertaken on the 10th , 22nd, 29th of July, 5th and 13th August from both blocks. At each harvest date the fruit was hand picked from 20 plants per plot and inspected for insect damage. Fruit were graded for size based on large fruit 10 – 15 cm long, medium fruit 5 – 10 cm and small fruit 0 – 5cm long.

Heliothis pheromone traps located near the trial site were used to monitor moth activity.

Section 2 (a) - Evaluation of predatory mites on Thrips and netting as a physical barrier to pests.
In a block of capsicum, 6 plots each 8 metres long x 2 beds of Capsicum were marked out in a completely randomised block design. Each plot was separated by 2 beds and by 2 metres along each row.

Prior to the seedlings being planted into the field they were sprinkled with predatory mites *Typhodromips montdorensis* over the top of the seedlings still in the trays. The mites were supplied through the Entomology Section, National Centre for Greenhouse Horticulture, Horticulture Research and Advisory Station, Gosford NSW. The sample sent was a "hot spot" formulation with *Tyrophagus sp.* mites as a food source. The first application was 750mls containing 15000 predatory mites. A second application was put on the plants in the field 20 days later.

Netting was loosely placed over the beds and the side of the netting buried in the soil along the side of the plastic mulch.

The following treatments were applied:

A.	Agryl P10	Agriweb netting
B.	Agryl P 17	Agriweb netting
C.	Success	120a.i/L Spinosad Naturalyte
D.	Avatar	300a.i/kg Indoxacarb
E.	Control	
F.	Control	

The treatments A & B were not seeded the second time and treatments C and D were applied in water at the rate of 833L/ha by a motorised knapsack sprayer.

Insect populations were assessed on 5 randomly selected plants per plot and mite populations were counted under a microscope from 5 leaves per plot. The netted treatments A & B were not sampled.

Section 2 (b) - Evaluation of predatory mites on Thrips.
A block of capsicum with 3 plots each 10 metres long x 10 beds were marked out and randomly allocated a treatment.

Treatments were:
A. Plants sprayed with water and mites sprinkled onto the damp leaves.
B. Mites sprinkled onto dry leaves.
C. Mites sprinkled around the base of the plants.

Montodorensis mites were supplied as for those in section 2 (a). Three samples were supplied and each sample was applied as a treatment. Only 1 application was applied.

To measure mite populations, 20 randomly selected leaves were collected from each treatment. Counting the number of mites on these leaves was made under a microscope in the laboratory.

Thrips counts were made by randomly collecting 10 flowers from each treatment. These flowers were placed in alcohol and returned to the laboratory where the thrips numbers were counted under a microscope.

Section 3 - Structure of capsicum plants and sampling techniques.
A block of capsicum with 5 plots each 10 metres long x 10 beds wide was used.

Sampling of the plants to determine insect populations was undertaken by 2 different methods as outlined under "Sampling methods".

In understanding where the insects are found on the plants, the structure of the capsicum plant was mapped. All insects found in each section of the plants were recorded.

<u>Plant structure</u>
The structure of capsicum plants was determined by counting the number of leaves and branches arising off the main stem, counting the secondary branches and leaves that arose off these as well as the number of flower buds, flowers and fruit arising from all parts of the plant. The top part of the plant that developed after the 9^{th} or 10^{th} branches was referred to as the throat.

<u>Sampling methods.</u>
A. *Whole plants* – Within each of the 5 plots, 2 plants were cut off at the base, placed in plastic bags and put into a freezer. These plants were then inspected for insects under a microscope in the laboratory. Every leaf and stem was examined.

B. *Sub-sampling* – Approximately every week, 4 randomly selected plants within each of the 5 plots were examined. On each on these plants 5 randomly selected leaves were inspected for insects.

The plant structure and the 2 sampling methods were undertaken on 8 separate dates approximately 1 week apart starting on the 24th May, 4 weeks post planting. Sub-sampling was not undertaken on the 26th June and 8th July.

Egg parasitism

For determining Heliothis egg parasitism, Heliothis eggs were collected from the field, placed individually in plastic cells which were then covered with plastic sheeting (gladwrap). These were held at 25^0 C in the laboratory. Eggs were checked daily and emergence of wasps recorded. The percentage of eggs parasitised was calculated from those eggs parasitised compared to total number of eggs collected.

Pheromone traps.

Pheromone traps were used to monitor the Heliothis moth flight activity from the trial site. Traps were inspected and serviced weekly.

Section 4 – commercial crop studies.

2002.

In commercial capsicum crops, scouting for insects pests was undertaken between 17th April and the 19th June 2002. Three crops were surveyed. One was a mature crop with fruit, the 2nd approximately 2 weeks younger and starting to fruit and the 3rd block another 2 weeks younger than the second. This crop was not flowering. Twenty plants per block were randomly selected throughout the crop and 5 randomly selected leaves per plant were examined. These crops were not to be sprayed unless insect numbers indicated otherwise.

In another commercial capsicum crop that was regularly sprayed, scouting for insect pests was undertaken between 19th June and the 4th July 2002. Twenty randomly selected plants within one block were selected and 5 leaves per plant were examined. This was a mature crop with fruit.

2003 (a).

A commercial block of capsicum 10 rows each 200 metres long was made available to us by the grower to undertake this trial. The control of insects through applications of insecticides was only to be used if the insect numbers recorded during the sampling reached damaging levels. A second block of a similar size was alongside this block and monitored by commercial consultants. Sampling in the trial block to monitor the insect populations was undertaken by 2 people. This observation block was divided into 2 sections, each 100 metres long. Within each of these sections 25 plants were randomly selected. These plants were selected by crisscrossing the 10 rows 5 times, selecting a plant every 2 rows. This gave a total of 25 plants per section or 50 in total for the block. On each of the plants, 5 randomly selected leaves were examined and the insect numbers recorded.

On the 14th April, 2 randomly selected plants were collected. They were cut off at ground level and returned to the laboratory to count the numbers of Heliothis eggs, larvae and thrips. This was to determine whether the field sampling method was detecting adequate numbers of these insects.

Collections of Heliothis eggs were undertaken to note parasitism levels.

Thrips counts in the field were made by randomly selecting 5 flowers on each sample date, placing them in alcohol and counting the numbers under a microscope.

Harvesting of fruit was undertaken on the 4th June. In five randomly selected areas throughout the block, one-metre long sections of row were stripped of fruit in both the trial block and in the adjacent block that was being monitored by commercial consultants. Fruit were separated into green and red as well as large and medium size and individually examined for damage. Damage was noted as that caused by insects or sunburn.

2003 (b).
This observation site was part of a commercial block of capsicums planted on the 12th June 2003. The row length within this area varied from 100 to 150 metres and each block was 10 rows wide. The total observation area monitored was 130 rows and this was approximately ½ of the total area under capsicums. To monitor for insects the observation area was divided into 4 sections with section 1 having 60 rows approximately 100 m long, section 2 with 30 rows approximately 120m long and sections 3 & 4 each with 20 rows approximately 150m long. Within each of these sections, 25 plants were randomly selected.

Sampling was undertaken throughout each section by randomly selecting the plants. On each of these plants, 5 randomly selected leaves were examined. Sections 1 & 2 were sprayed as per the growers schedule and sections 3 & 4 sprayed as required, based on insect numbers. All blocks had a spray of Methamidophos (Nitofol) applied just after planting as a precaution against insects. Sampling to monitor the insect populations was undertaken by 2 people. In sampling Heliothis, ladybird beetles and lacewings, the egg, larval or nymph stages were recorded as well as the adults of the latter two.

Thrips counts were made by randomly selecting 5 flowers on each sample date. Counts were made under a microscope in the laboratory.

2003 (c).
On the research station a block of capsicum with 5 plots each 10 metres long x 2 beds of plants were marked out so that sampling was distributed throughout each block. No insecticides were applied to this crop.

To evaluate insect populations, 5 randomly selected plants within each plot were inspected.

Pheromone traps for both *Helicoverpa armigera* and *H. punctigera* were used to monitor moth activity in all of the observations.

RESULTS

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

Table 13 gives the aphid population recorded on 125 leaves per treatment with the total number of aphids recorded on 750 leaves.

Table 13. Number of aphids on 125 leaves per treatment and total on 750 leaves.

Date	Total	Treatment					
		A	B	C	D	E	F
4/9	4423	761	786	768	854	673	581
11/9	289	48	42	76	19	90	14
18/9	65	11	20	13	4	13	4
25/9	31	4	6	5	5	4	7
3/10	174	15	18	26	39	59	17
10/10	673	44	60	66	104	42	357
17/10	1630	86	188	353	677	107	219
22/10	954	43	26	84	596	125	80
31/10	17	3	2	1	10	1	0
7/11	34	0	15	5	2	0	12
14/11	0	0	0	0	0	0	0

Analysis (GenStat 2002) of the data shows no significant difference between the treatments following the insecticide application on the 28th September.

This data showed the total aphid population decreased from 4423 to 31 aphids between the 4th and the 25th September prior to the insecticide application. This was due to the beneficial insect activity, mainly ladybird beetles and parasitic wasps.

Following the application of the insecticide treatment, the total aphid population increased up until the 17th October and then began to decrease with increasing beneficial insect populations.

Table 14 shows the number of the beneficial insects (ladybird beetles, lacewings, parasites and spiders) recorded on the leaves. The total does not include the insect stages that do not feed on the aphid populations i.e. eggs. The parasite count is based on mummified aphids and not individual wasps.

Table 14. Number of beneficial insects recorded on 125 leaves.

Date	Ladybird beetles			Total	Lacewings			Total	Wasps	Spiders
	Eggs	Larvae	Adults		Eggs	Larvae	Adults		Total	Total
4/9	5.5	1.8	4.5	**6.3**	3.2	0	0	**0**	**9**	**0.8**
11/9	1.3	0.7	9.3	**10**	4.5	0	0	**0**	**7.8**	**0.3**
18/9	0	0	1	**1**	1.7	0	0	**0**	**2.3**	**0**
25/9	0	0	0.7	**0.7**	0.8	0.8	0	**0.8**	**0.7**	**0.5**
3/10	0.7	0	1.5	**1.5**	1	0	0.2	**0.2**	**0.5**	**0.8**
10/10	2.7	0.3	0.7	**1**	2.7	0	0	**0**	**0.5**	**0.5**
17/10	2.0	0.8	2.5	**3.3**	4.8	0	0.3	**0.3**	**3.8**	**0.8**
22/10	33.3	1.3	4.3	**5.6**	1.2	0.5	0.2	**0.7**	**2.2**	**0.2**
31/10	0	0.2	12.6	**12.8**	0.2	0	0	**0**	**0.5**	**0**
7/11	0	0.5	4	**4.5**	2.7	0	0.2	**0.2**	**0**	**0.2**
14/11	0	0	0	**0**	0	0	0	**0**	**0**	**0**

Analysis of the data showed significant differences between the treatments on the 3rd October where there the Control treatment had significantly more spiders than in the other treatments.

Table 14 also shows that the majority of the beneficial insects recorded were ladybird beetles and parasitic wasps. The relationship between the aphid population decline and these two beneficial insects is given in Figure 1.

Figure 1. Relationship between aphid populations and the ladybird beetles and parasitic wasp populations.

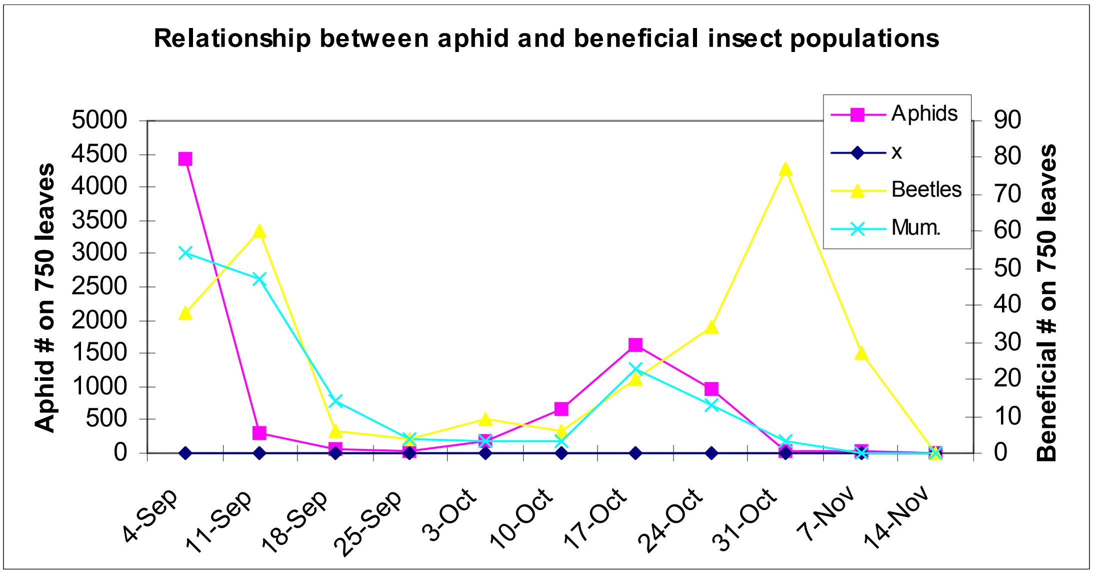


Figure 1 shows the effectiveness of the beneficial insects in controlling the aphid populations prior to the insecticide application. The effectiveness of the beneficial insects in reducing aphid populations occurred within 1 week.

The beneficial insect numbers decreased as aphid numbers declined but was delayed by about 1 week. This decrease is a reflection of the lower number of hosts (aphids) being available and not the treatments.

Three weeks following the insecticide application, the total aphid population increased to 1630, an average of 2.17 per leaf. With a one-week lag time, beneficial insect populations started to increase and within 3 weeks, the aphid population had been reduced to nil with no more insecticides being applied. This reduction in aphid numbers was due to beneficial insects.

Analysis of the Heliothis egg and larval counts showed no significant difference between the treatments, possibility due to the low numbers recorded.

The low numbers of Heliothis recorded in this crop corresponds to the low number of moths collected in the pheromone traps placed within the vicinity of this trial site. Refer to Figure 2.

Figure 2. Number of *Helicoverpa armigera* moths taken from pheromone trap at Ayr during 2001.

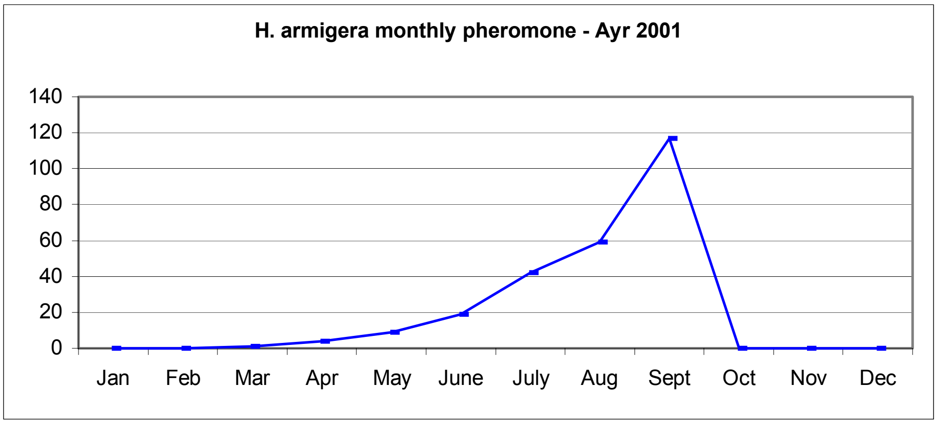


Table 15 gives the number and percentage of fruit damaged by Heliothis.

Table 15. Mean number of damaged and the percent of damaged fruit per treatment over 3 harvesting periods.

	Pick 1		Pick 2		Pick 3		Total	
Treat	**# Damaged**	**% Damaged**	**# Damaged**	**% Damaged**	**# Damaged**	**% Damaged**	**# Damaged**	**% Damaged**
A	1.0	1.92	0.8[a]	3.05[a]	0.4	0.7	2.2	1.61[a]
B	1.2	1.77	0.2[a]	0.83[a]	0.0	0.0	1.4	0.9[a]
C	1.6	2.81	0.2[a]	0.61[a]	0.6	1.07	2.4	1.75[a]
D	2.0	4.1	0.2[a]	0.69[a]	0.8	1.16	3.0	2.14[ab]
E	0.6	1.14	0.4[a]	1.41[a]	1.0	1.81	2.0	1.36[a]
F	1.6	3.14	2.2[b]	8.89[b]	1.4	3.2	5.2	4.08[b]

Numbers followed by the same letter are not significantly different at the 0.5% level.

Analysis of the data showed that all of the insecticides had significantly less numbers and percentage of damaged fruit than the Nil-sprayed treatment in the second pick. This difference was similar in the total percentage of the three picks for the damaged fruit, though the Rimon treatment was not significantly different to the Nil-spray treatment.

Table 16 gives the number and average number of fruit picked per plant over these 3 harvest periods. The number of fruit picked includes damaged fruit.

Table 16. Number of plants and fruit picked over 3 periods with mean number of fruit picked per plant.

	Pick #1			Pick # 2			Pick # 3			Average
Treat	**Plants**	**Fruit**	**Av. # of fruit**	**Plants**	**Fruit**	**Av. # of fruit**	**Plants**	**Fruit**	**Av. # of fruit**	**# of fruit per plant**
A	81	282	3.48	85	178	2.09	76	250	3.29	8.86
B	77	295	3.83	78	157	2.01	73	266	3.64	9.48
C	82	324	3.95	81	159	1.96	75	252	3.36	9.27
D	78	280	3.59	77	131	1.70	76	326	4.29	9.58
E	82	300	3.66	83	165	1.99	84	301	3.58	9.23
F	89	286	3.21	89	145	1.63	87	251	2.89	7.73

There was no significant difference between the treatments in the number of fruit picked per plant.

The average number of fruit picked per plant ranged from 7.73 to 9.58.

Section 1 (b) - Comparisons between a sprayed (A) and an unsprayed (B) crop on insect populations.

Table 17 gives the average number of insect pests per plant found in the unsprayed crop (B). Numbers of some insect pests were very low and are not shown in this table.

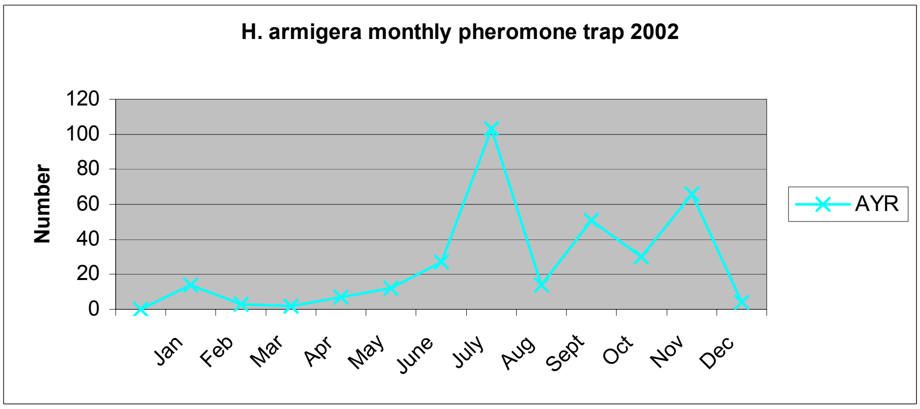
Table 17. Average number per plant of the insect pests found in Block B.

Date	Heliothis		Aphids	SLWF	Thrips	Cluster caterpillar	Crickets	Jassids
	Eggs	Larvae						
4/6	0.33	0.07	0.13	9.4	0	0	0	0.13
13/6	0.07	0	5.2	2.13	0.07	0.07	0.13	0.07
19/6	0.33	0	3.27	7.27	0	0	0.07	0.13
			Second sampling period					
22/7	0.1	0	7.2	0.5	0	0	0	0
29/7	0.8	0	1.5	1.7	0	0	0	0
5/8	0.1	0	0.1	0.6	0	0	0	0
13/8	0	0	0	1.6	0	0	0	0

Table 17 shows that from the number of Heliothis eggs recorded, no larvae were recorded in the following sampling period. This could indicate that the sampling method used may not be satisfactory to indicate larval numbers. Heliothis larvae tend to move into the flowers and fruit, as this is the preferred feeding area. There is also the possibility that the survival rate from eggs is low due to predation or egg parasitism.

Flight data from pheromone traps (Figure 3) indicated that there was an increase in moth activity from mid-June. This corresponds to the interval in which this trial was undertaken.

Figure 3. Monthly pheromone trap catches of *Helicoverpa armigera* moths at Ayr Research Station during 2002.



The highest oviposition period occurred on the 29th July in Block B and this corresponds to the highest number of moths taken at the pheromone traps.

The average number of aphids per plant varied from 0.13 to 5.2 within the first 3 weeks. In the second sampling period, the numbers increased to 7.2 per plant but this was reduced by beneficial insect activity within 7 days.

Capsicum plants are not considered a major host of silverleaf whitefly (SLWF), although the population reached a maximum of 9.4 per plant. As sampling continued this number declined to an average of 1.1 per plant throughout the second sampling period of 27th July to the 13th August.

Table 18 gives the average number of beneficial insects recorded. Some of the beneficial insects recorded are not shown, as their numbers were very low.

Table 18. Average number per plant of the beneficial insects found in Block B.

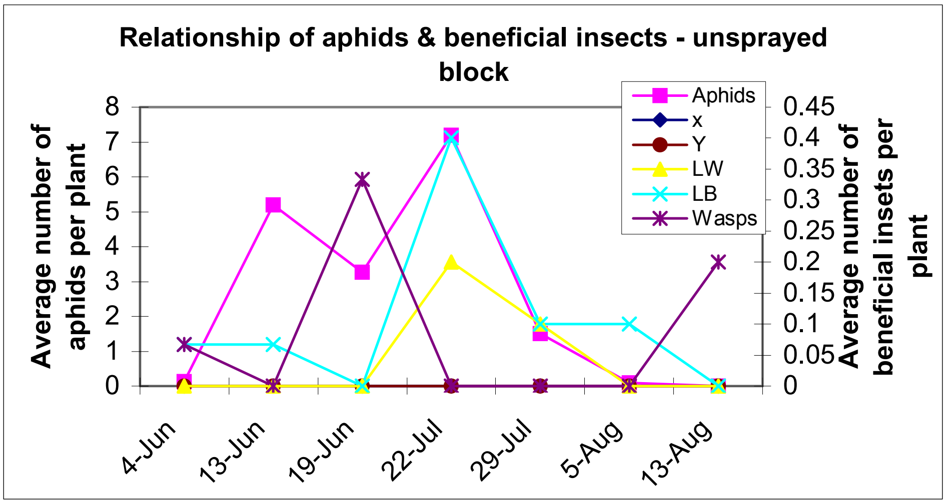
Date	Lace wings	Ladybird beetles	Parasitic wasps	Spiders
4/6	0	0.07	0.07	0.2
13/6	0	0.07	0	0.07
19/6	0	0	0.33	0.2
		Second sampling period		
22/7	0.2	0.4	0	0.5
29/7	0.1	0.1	0	0
5/8	0	0.1	0	0
13/8	0	0	0.2	0

Table 18 shows that the main group of beneficial insects controlling the aphid populations were ladybird beetles, aphid parasites and spiders. In the second sampling period, lacewings also contributed with decreasing numbers of aphid parasites and spiders.

The low number of beneficial insects is considered to be due to the low aphid populations and this relationship is shown in Figure 4.

Figure 4 shows the fluctuations of the aphid population over the two sampling periods and how the beneficial insects reduced these populations. Mummies (parasitised aphids) can remain high, even after the aphid population has disappeared, as these infected bodies do not fall off the leaves even after the adult wasp has emerged.

Figure 4. Relationship of aphids & beneficial insects in an unsprayed block of capsicum.



Comparisons between the insect populations in the commercially sprayed block (A) and the unsprayed block (B) are given in Table 19. All of the insect species recorded are not tabled due to the low populations.

Table 19. Average number per plant of the insect pests found in Blocks A & B.

Date	Block	Heliothis		Aphids	SLWF
		Eggs	Larvae		
22/7	B	0.1	0	7.2	0.5
29/7	A	0.1	0	46.3	0.5
	B	0.8	0	1.5	1.7
5/8	A	0.1	0	60.1	0
	B	0.1	0	0.1	0.6
13/8	A	0	0	44.2	0
	B	0	0	0	1.6

Table 19 shows little difference between the sprayed (A) and unsprayed (B) blocks in the Heliothis numbers. The aphid population is much higher in the sprayed block.

The numbers of the other insects are too low to have measurable effect on yields.

Table 20 gives the average number of beneficial insects recorded in blocks A & B.

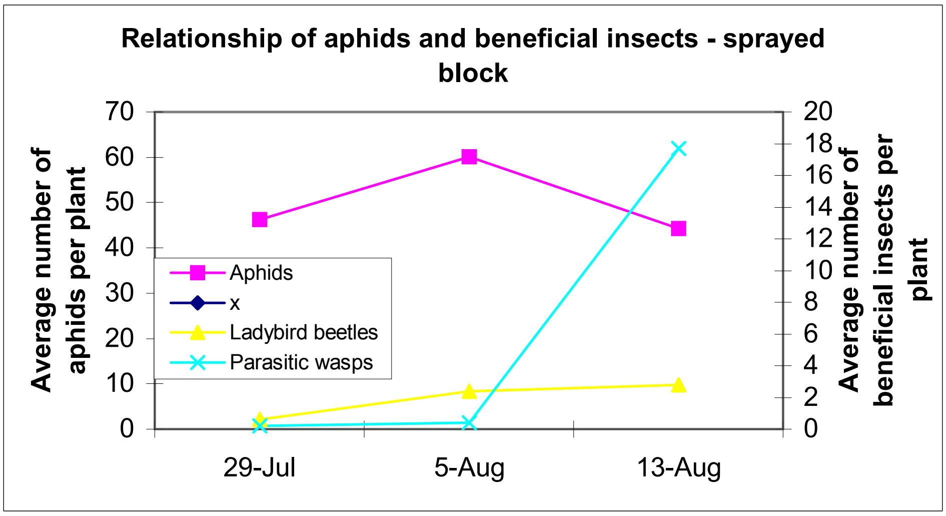
Table 20. Average number per plant of the beneficial insects in Blocks A & B.

Date	Block	Ladybird beetles			Lacewings			Parasitic wasps	Spiders
		Eggs	**Larvae**	**Adults**	**Eggs**	**Larvae**	**Adults**		
22/7	B	0	0	0.4	2.3	0.1	0.1	0	0.5
29/7	A	0	0.5	0.1	2.1	0.1	0.3	0.2	0.2
	B	0	0	0.1	1	0.1	0	0	0
5/8	A	0	1.9	0.5	0.5	0.1	0.5	0.4	0
	B	0	0	0.1	0.5	0	0	0	0
13/8	A	0.4	1.1	1.7	2.8	0.1	0.3	17.7	0.2
	B	1.7	0	0.3	1.6	0	0	0.2	0

These data show that the beneficial insect numbers have increased in the sprayed block
(A). The group that increased the most were the aphid parasites as shown on the last sampling date 13/8. These parasite populations controlled the aphid population to a level that would not be causing problems.

Figure 5 shows the relationship of the beneficial insects to the aphid population. Even though the sampling stopped on the 13th August, past results have indicated that with an increasing level of aphid parasitism the aphid population would continue to decline, and do so within a short period.

Figure 5. Relationship between numbers of aphids and beneficial insect, in a sprayed capsicum block.



The number of damaged and undamaged fruit harvested from 5 picks is given in Table 21.

Table 21. Fruit harvested from an unsprayed (B) block and a sprayed (A) block of Capsicum.

		Un damaged fruit			Damaged fruit				
Date	**Block**	**Large**	**Medium**	**Small**	**Large**	**Medium**	**Small**	**Total fruit**	**% damaged**
10 July	A	59	156	0	2	5	0	222	3.15
	B	52	152	0	3	11	0	218	6.42
22 July	A	32	37	55	1	0	0	125	0.8
	B	38	26	28	2	1	1	96	4.17
29 July	A	41	55	65	1	1	0	163	1.23
	B	43	30	49	2	1	0	125	2.4
5 August	A	43	51	75	3	0	1	173	2.3
	B	40	21	59	1	0	1	122	1.6
13August	A	49	51	46	3	1	1	151	3.3
	B	48	38	35	4	3	1	129	6.2

Analysis of the data showed significantly more fruit was harvested from the sprayed block than the unsprayed block. This difference was in the medium and small fruit categories.

There was no significant difference between the 2 blocks in the percentage of damaged fruit. The highest level of damage reached 6% on the 1st pick and most of the damaged fruit were in the medium sized fruit category.

Section 2 (a) - Evaluation of predatory mites on Thrips and netting as a physical barrier to pests.

Table 22 gives the number of pests and beneficial insects recorded on the plants.

Table 22. Insects recorded on 25 leaves per plot.

Date	Treatment	Heliothis	Aphids	Silverleaf whitefly	Thrips	Mites	Leafhopper	Leaf miner	Cricket	Aphid parasites	Spiders
15/10	**Spinosad**	1		11	3	1					
	Avatar			1	2	0					
	Control			4	0	0					
	Control			2	2	0	1				
22/10	**Spinosad**			53	2	0					
	Avatar	1		61	10	2		1		1	
	Control			120	2	3			1	1	2
	Control			80	6	3				1	
5/11	**Spinosad**			20	11	106					
	Avatar			18	4	56					
	Control			16	4	109					
	Control			20	1	58					
11/11	**Spinosad**		4	37	7	67					
	Avatar			36	3	63					
	Control			25	2	75					
	Control			33	5	51					

Counts from the plots covered with netting were not made. Silverleaf whitefly numbers increased between the 1st and 2nd sampling dates but fell over the next 2 sampling dates. Heliothis and aphid numbers were near undetectable. Thrips were present in this crop and Tosporvirus was evident. The increase in virus-infected plants is common for crops planted at this time of the year in the Dry Tropics. Predatory mite numbers were low in the 1st two sampling periods but increased for the next 2 sampling dates.

Section 2 (b) - Evaluation of predatory mites on thrips.

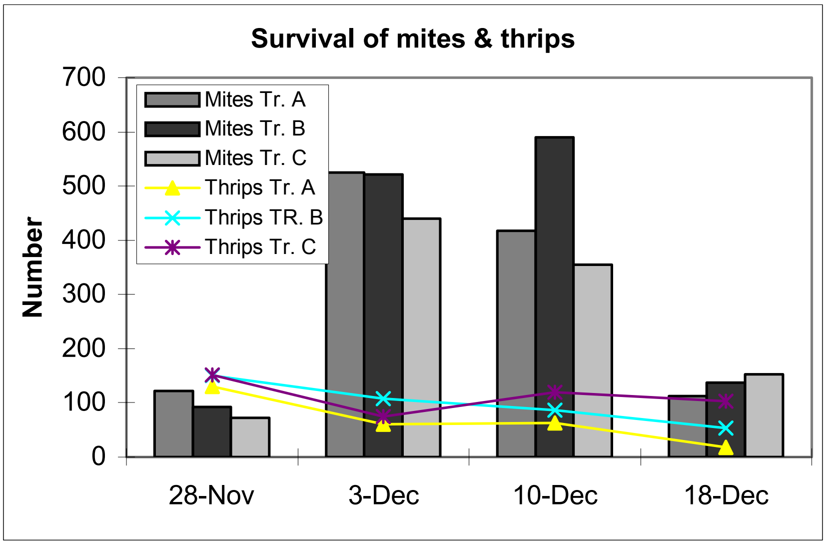
Table 23 gives the number of thrips and mites collected from the three treatments. Samples of the thrips indicated that approximately ¾ of the numbers were nymphs indicating thrips populations were established and increasing.

Table 23. Number of thrips in 10 flowers and number of mites on 20 leaves for 3 treatments over 4 sampling periods.

Date	Treatment A		Treatment B		Treatment C	
	Thrips	Mites	Thrips	Mites	Thrips	Mites
28/11	130	122	150	92	151	72
3/12	60	525	108	521	75	440
10/12	63	417	86	590	120	355
18/12	18	112	53	137	103	152

Analysis of the data showed that there were no significant differences between the treatments in the number of mites or thrips collected. This indicates that any of these 3 seeding techniques for mites will be satisfactory in establishing mite populations in field-planted capsicum crops. The mite populations increased in the 2nd and 3rd sampling dates from those on the 1st sampling date. This coincides with the reducing thrips populations and is shown in Figure 6. Whether the mites are causing this reduction could not be proven in this trial. The reduction in mite numbers on the last sampling date could be due to low thrips numbers and the mite population declining through starvation, indicating that the mites could have been responsible for the thrips decline.

Figure 6. Survival of mites & thrips on capsicum.



Section 3 - Structure of capsicum plants and sampling techniques.

Plant structure.

Mapping the structure of capsicum plants showed that the number of leaves arising from the main stem was approximately 9 - 10 leaves, alternate in pattern. Arising from the junction of each leaf on the stem, a branch develops. After the last top leaf on the stem, the stem divides into multi stems or branches usually with the first large fruit developing in the throat. Refer to Appendix 2, Figures 1 & 3.

At each leaf and stem junction a branch develops and along this branch the first 2 leaves are opposite, followed by the other leaves that are alternate. In the majority of the plants there are 3 - 4 leaves prior to this branch dividing into sub-branches. The number of sub-branches per branch is 3 – 4, usually with a flower in the throat at this division. Refer to Appendix 2, Figure 2. This structure is replicated as it grows out along these sub-branches.

In studying the relationship between the plant and where insects are found on the plant, the structure of the plant allowed it to be divided into 4 sections. The bottom 3 branches and their sub-branches are referred to as the bottom 1/3rd of the plant. The next 3 branches and their sub-branches as the middle part of the plant and the top 3 or 4 branches and their sub-branches including the sub-branching above this point as the top 1/3rd of the plant. The 4th section of the plant is referred to as the throat and includes the 1st major fruit.

Table 24 gives the average number of leaves, flower buds, flowers and fruit found in the 3 sections of the plant along with the number of flower buds, flowers and fruit for the throat area. A total for the average number of fruit produced per plant is also given.

Table 24. Composition of the 4 sections of a capsicum plant including the average number of fruit produced per plant.

Date	Bottom 1/3rd of plant				Middle 1/3rd				Top 1/3rd				Throat			Total
	Av. # of leaves lant	Fl. buds	Flowers	Fruit	Av. # of leaves	Fl. buds	Flowers	Fruit	Av. # of leaves	Fl. buds	Flowers	Fruit	Fl. buds	Flowers	Fruit	Fruit average
24/5	16	3.2	0	0	6.8	1.2	0	0	11.1	7.4	0.1	0	0.4	0	0	0
29/5	21.3	4.3	0	0	12.3	1.7	0	0	21.1	13.9	0	0	0.7	0	0	0
4/6	26	6.3	0	0	15.3	2.3	0	0	31.3	17.7	0.4	0	0.4	0.6	0.1	0.5
11/6	39.3	12.7	0.4	0.7	20	2.2	0.2	0.1	69.3	31.3	2.7	2.5	0.1	0	0.7	4.0
19/6	45	12.8	2.3	2.1	20.8	1.6	0.7	1	74.6	24.8	5.9	5.8	0	0	0.9	9.8
26/6	34.6	5.8	1.5	2.3	18.5	1	0.6	0.5	74.8	14.9	6.1	6.7	0	0	1.1	10.6
4/7	37	3.8	0.8	2.1	18.6	0.9	0	0.1	81.7	16.6	5.2	7.2	0	0	0.8	10.5
8/7	35.4	3.3	0.8	1.7	19.7	1.2	0.3	0.5	93.5	15	5.1	7.5	0	0	1	10.7

These data show that the majority of the plant growth is generated in the bottom 1/3rd and the top 1/3rd of the plant. Refer to Figure 7. Leaves in the top part of the plant include those from the top 3 branches and those on the sub-branches arising from the throat area. This has increased the number of leaves in this section of the plant.

Figure 7. Average number of leaves per plant in the bottom, middle and top 1/3rds of the plant.

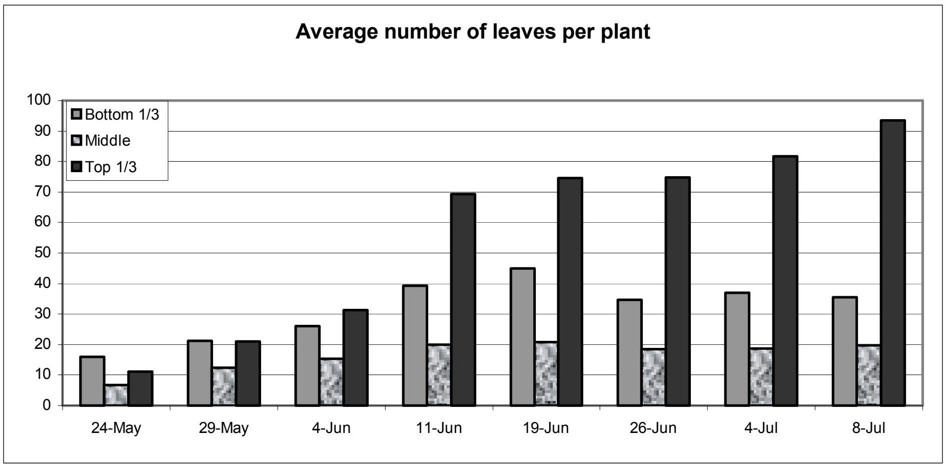


Figure 7 shows that the amount of leaf material in the bottom 1/3rd of the plant is the highest on the first sample date, equal to the average amount of leaf of the top 1/3rd of the plant within one week and reaches a peak on the 5th sampling date. It then reduces by approximately 10% over the rest of the sampling periods due to leaf fall that could be caused by disease.

The middle 1/3rd of the plant has approximately 50% of the leaf material of the bottom 1/3rd of the plant throughout the sampling periods.

The top 1/3rd of the plants leaf material continues to increase with the biggest increase of approximately 40% noted between the 3rd and 4th sampling dates. Increase in leaf material in the top 1/3rd of the plant slowed after the 4th sampling, increasing by approximately 20% between that sample date and the last.

The data in Table 24 also show that more flowers and fruit are produced in the bottom section compared to the middle section, but overall the majority of flowers and fruit are produced in the top section of the plant. Refer to Figures 8 & 9.

The first flowers to appear occurred in the top section of the plant on the 24th May. The first fruit were recorded from the plants on the 4th June in the bottom and top sections of the plant. The main plant activity period for flowering and fruit set occurred approximately 6 weeks after planting out into the field.

Figure 8. Flowering pattern for different sections of the capsicum plants.

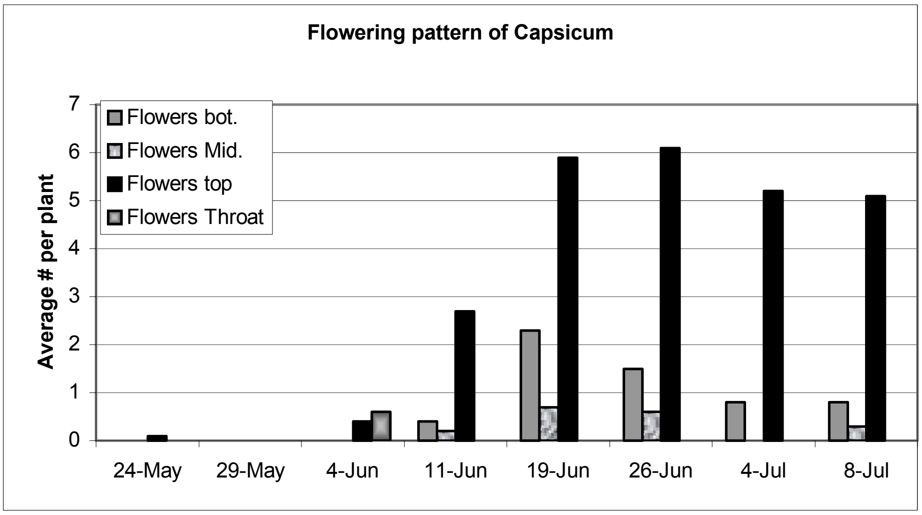


Figure 8 shows the dominance of flowers in the top section of the plant compared to the other 2 sections. The throat area is not expected to have many flowers as it refers to a small area in the top of the plant.

Figure 9 shows the average number of fruit produced per plant is approximately 9 to 10 fruit. The majority of these are produced in the top section of the plant followed by the bottom section and an average of 1 fruit from the throat section of the plant.

Figure 9. Fruiting pattern for different sections of the capsicum plants.

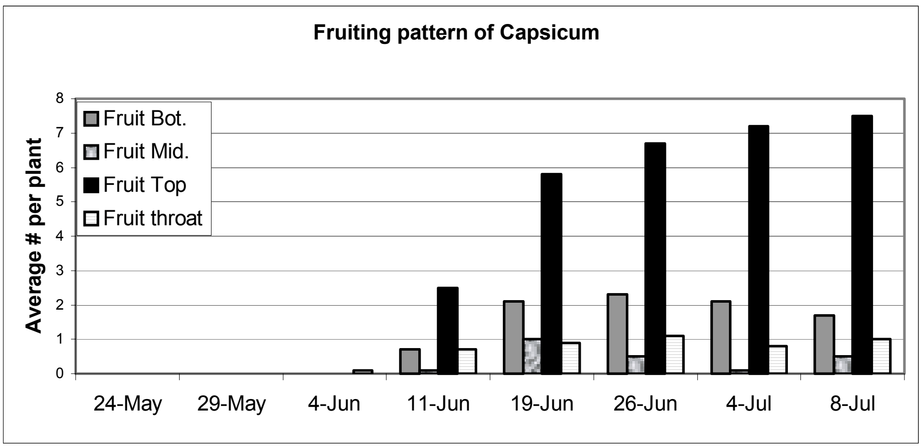


Table 24 also showed that the highest average number of fruit produced per plant is 10.7 and confirms that if growers accept a 10% damage threshold, approximately 1 fruit per plant can be lost or damaged under an IPM system.

Sampling methods

A. *Whole plants*.

Recording of the insects and where they were found on the plant indicated that less than 5% were dislodged from the plant and most remained in situ. Those that were dislodged were adult forms that could fly.

Heliothis are pests of all parts of the capsicum plant inflicting the most damage through eating flowers and fruit. The eggs are not a problem but the larvae are. Egg counts are used to give an indication of the Heliothis larval population that can develop in a crop.

Table 25 gives the position on capsicum plants where Heliothis eggs and larva are found. The average numbers of insects per plant have been recorded for the 4 different sections of the plant as defined in the plant structure results.

Table 25. Heliothis eggs and larva found in the 4 sections of capsicum plants.

Date	Whole plant sample							
	Bottom 1/3 of plant		Middle 1/3 of plant		Top 1/3 of plant		Throat of plant	
	Av. per plant		Av. per plant		Av. per plant			
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
24/5	0.3	0	0	0	0.3	0	0	0
29/5	0	0	0.1	0	0.5	0	0	0
4/6	0.8	0	0.4	0	0.6	0.1	0	0
11/6	0	0	0.3	0.1	0.5	0	0	0
19/6	0	0	0.2	0	0.6	0	0	0
26/6	0	0	0	0	0.4	0	0	0
4/7	0.2	0	0.1	0	0.4	0	0	0
8/7	0	0	0.1	0	0.5	0	0	0

Table 25 shows that there are regularly more eggs laid in the top 1/3rd of the plant compared to any other section of the plant. Over the sampling periods, 20.6% of the total eggs recorded were laid in the bottom 1/3rd of the plant, 19.0% in the middle1/3rd and 60.3% in the top 1/3rd of the plant. Only 2 larvae were found in sampling the whole of the plant, one in the middle and 1 in the top 1/3rd of the plant. This shows that not all of the eggs hatch or the emerging larvae survive.

Figure 10 shows the relationship of the egg numbers recorded per plant during this period.

Figure 10. Relationship of egg numbers to the plants reproductive period.

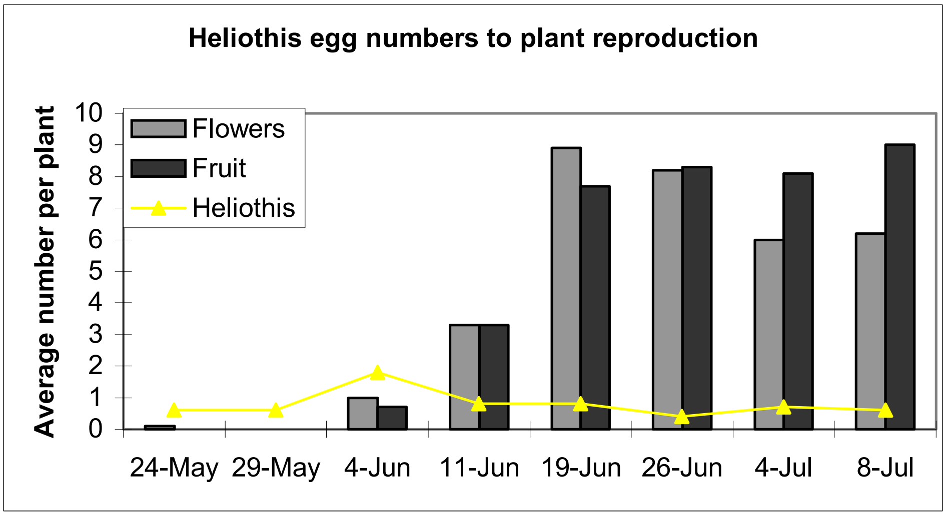


Figure 10 shows the number of eggs laid is not related to the plants reproductive period. This could have been due to very low Heliothis moth activity as shown in Figure 11.

Figure 11. Moth catches at pheromone traps

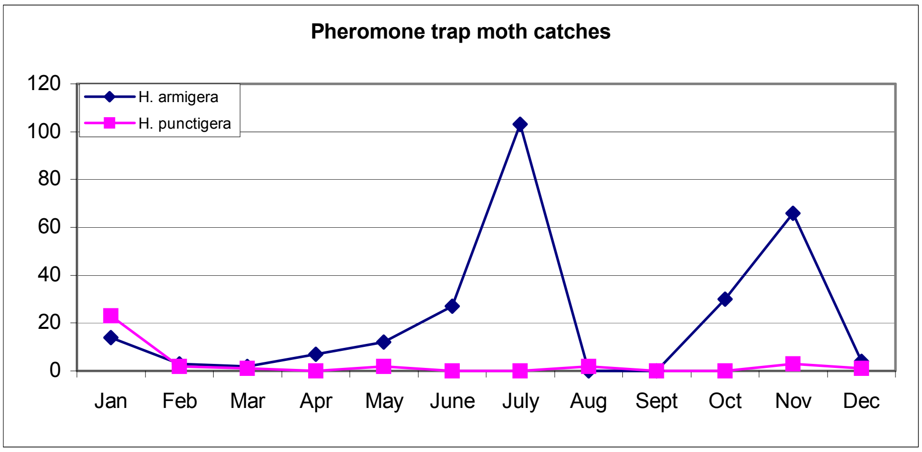
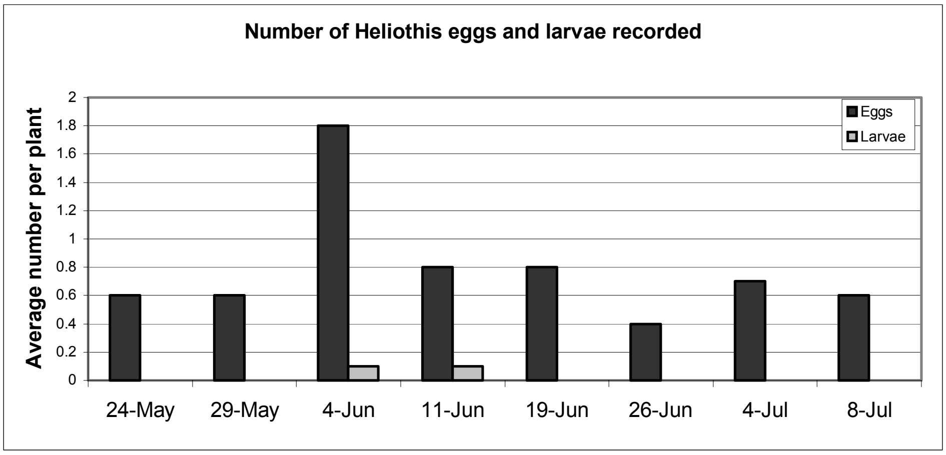


Figure 12 shows the average number of larvae found from the eggs laid per plant. From the egg counts it would have been expected that more larvae would have been detected, as whole plants were sampled. The effect of predators and egg parasites can influence the numbers that emerge and in this trial parasitism levels reached an average of 57% between the start of sampling and the 11th June. The average level of parasitism dropped after this period to 22%. These parasitism levels do not account for the low number of larvae that were detected in the plant samples. Other factors are also important when considering egg numbers to predict larval numbers.

Figure 12. Numbers of Heliothis eggs and larvae detected.



Heliothis larvae emerge from the egg in 4 days under approximately 25^0C (Cotton Logic V 5.00 2002). Using 4 to 5 days for the eggs to emerge, we can roughly estimate how many eggs would have been detected prior to a larvae being detected.

From the number of larvae detected on the 4th June it is estimated that an average of 1.0 egg per plant would have detected on the 31st May. From larvae detected on the 11th June an average of 1.7 eggs per plant would have been recorded on the 6th June. From the other sampling periods, where no larvae were detected, the egg numbers did not average above 0.8 eggs per plant.

Table 26 gives the position on the capsicum plants where aphids are found. The average numbers of aphids per plant have been tabled for the 4 sections of the plant.

Table 26. Aphid numbers found in different sections of capsicum plants.

Date	Whole plant sample. Average number per plant.			
	Bottom 1/3 of plant	**Middle 1/3 of plant**	**Top 1/3 of plant**	**Throat**
24/5	0.4	0	0.3	0
29/5	0.3	0.3	0.3	0
4/6	0.8	1.1	0.7	0
11/6	0.5	0.3	6.3	0
19/6	0.2	0.3	9.0	0
26/6	6.6	0.2	8.9	0
4/7	7.2	0.5	12.4	0
8/7	14.3	3.9	30.2	0

Table 26 shows that aphids infest all leaves in all sections of young plants. It also shows that more aphids are found in the bottom and top 1/3rds of the plant compared to the middle leaves, and as the plant grows most aphid numbers are found in the top section of the plant. This is illustrated in Figure 13.

Figure 13. Aphid population trends as leaf numbers increase.

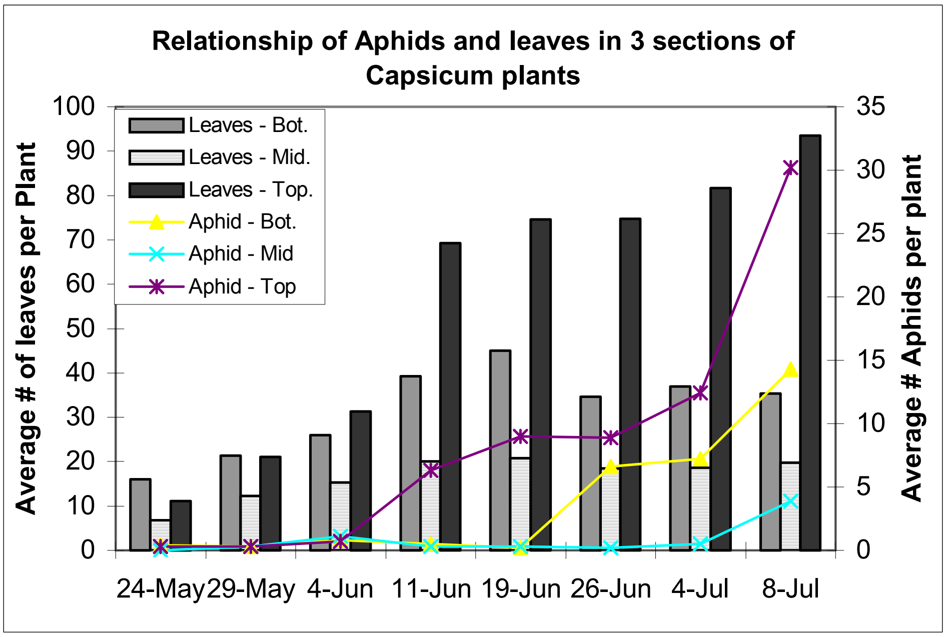


Figure 13 shows the aphid populations are distributed throughout the entire plant in the early growth period. Despite the low number of aphids, Figure 13 shows the subsequent rapid growth period coincides with an increasing aphid population in the top and bottom sections of the plant.

Thrips are recorded as pests of all parts of the capsicum plant. Through their feeding they can transmit Tosporviruses that can destroy crops.

Table 27 gives the position on the capsicum plants where thrips are found.

Table 27. Thrips numbers found in different sections of Capsicum plants.

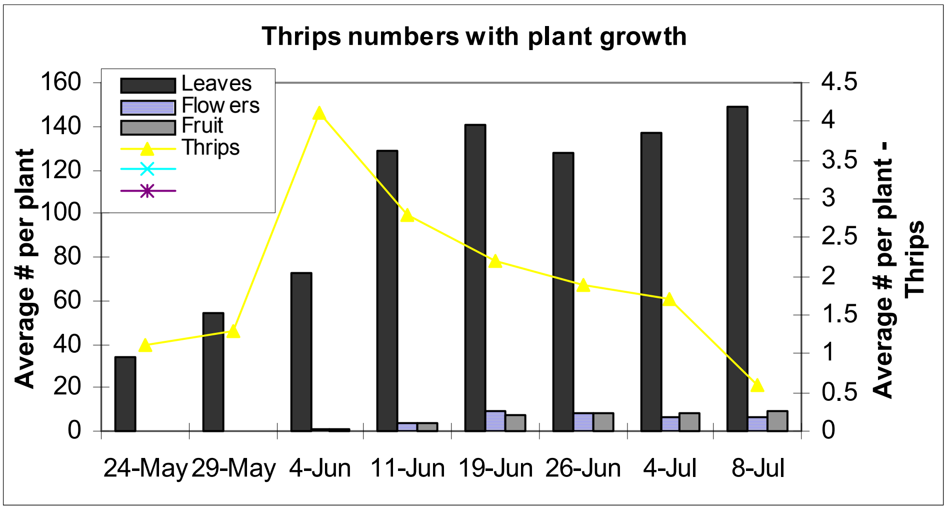
Date	Whole plant sample. Average number per plant			
	Bottom 1/3 of plant	**Middle 1/3 of plant**	**Top 1/3 of plant**	**Throat**
24/5	0.4	0.1	0.5	0.1
29/5	0.4	0.1	0.7	0.1
4/6	0.4	0.3	1.0	2.4
11/6	0.4	0	1.6 + 1.2*	0.8
19/6	0.1	0.2	1.9	0
26/6	0.5	0.1	1.3	0
4/7	0.1	0.3	1.3	0
8/7	0.1	0.1	0.4	0

* This population of thrips were recorded from under the calyx of one fruit.

Table 27 shows that the thrips populations were scattered throughout the entire plant. There is a slight increase in the numbers recorded from the throat area and this coincides with the start of the flowering on the 4th June. They were still present in the following sampling period then disappeared from that section. Whether this is due to the flower numbers in other sections of the plant is unknown.

Figure 14 shows the relationship between thrips numbers and the different plant growth stages. It shows that thrips populations peaked early in this crop and did not continue to increase as flower numbers increased.

Figure 14. Thrips populations in relation to capsicum plant growth.



The other insect pests recorded in this crop included silverleaf whitefly (SLWF), vegetable jassid, mites, cluster caterpillar and crickets. These groups of insects are regarded as minor pests in capsicum crops, though occasionally they can cause major problems.

Table 28 gives the number of SLWF recorded in the different sections of capsicum plant.

Table 28. SLWF numbers found in different sections of capsicum plants.

Date	Whole plant sample. Average number per plant			
	Bottom 1/3 of plant	**Middle 1/3 of plant**	**Top 1/3 of plant**	**Throat**
24/5	0	0	0	0.2
29/5	0	0	0.1	0
4/6	0.2	0.3	0.5	0
11/6	0.2	0.1	0.1	0
19/6	0.5	0	1.0	0
26/6	0.2	0	0.1	0
4/7	0.4	0	0	0
8/7	0.6	0.1	0.8	0

The numbers of SLWF recorded in Table 28 are considered low. In good host crops, populations of this insect can reach over 200 individuals per cm^2 (Brown unpub.). The data indicate that the leaves on the bottom and top $1/3^{rd}$ of the plants are where the populations could be found. The distinction between nymphs and adults of SLWF was not made in this table but it would be likely that the population on the bottom section of the plant would be nymphs and those in the top section adults.

Tables 29 and 30 give the numbers of vegetable jassid and mites (Table 29) and cluster caterpillar and crickets (Table 30), recorded in the different sections of the plant. The numbers of these insects were low and not considered high enough to cause problems.

Table 29. Vegetable jassid and mite numbers found in the different sections of capsicum plants.

Date	Whole plant sample. Average number per plant							
	Jassids				Mites			
	Bottom 1/3	Middle 1/3	Top 1/3	Throat	Bottom 1/3	Middle 1/3	Top 1/3	Throat
24/5	0.2	0	0.1	0.1	0	0	0	0
29/5	0	0	0	0.2	0	0	0	0
4/6	0	0	0	0	0.1	0	0	0
11/6	0.3	0	0.3	0	0	0	0	0
19/6	0	0	0	0	3.2	2.0	9.2	0
26/6	0	0	0	0	0.2	0.4	0	0
4/7	0	0	0	0	0	0	0	0
8/7	0.1	0	0.4	0	0.1	0	0.1	0

Table 30. Cluster caterpillar & cricket numbers found in the different sections of capsicum plants.

Date	Whole plant sample. Average number per plant							
	Cluster				Crickets			
	Bottom 1/3	Middle 1/3	Top 1/3	Throat	Bottom 1/3	Middle 1/3	Top 1/3	Throat
24/5	0	0	0	0	0	0	0	0
29/5	0	0	0	0	0	0	0	0
4/6	0.2	0	0	0	0	0	0	0
11/6	0	0	0	0	0	0	0	0
19/6	0	0	0	0	0	0	0	0
26/6	0	0	0	0	0	0	0.2	0
4/7	0	0	0	0	0	0.1	0	0
8/7	0	0	0	0	0.1	0.1	0.3	0

There are a number of beneficial insects that have been identified as feeding on the insect pest species. These are listed in the book "Insect Pest Guide". Tables 31 and 32 give the position on capsicum plants where ladybird beetles and lacewings were found.

Table 31. Ladybird beetle numbers found in the different sections of capsicum plants.

Date	Whole plant sample. Average number per plant											
	Bottom			Middle			T0op			Throat		
	Egg	Larvae	Adults	Egg	Larvae	Adults	Egg	Larvae	Adults	Egg	Larvae	Adults
24/5	0	0	0	0	0	0	0	0	0	0	0	0
29/5	0	0	0	0	0	0	0	0	0	0	0	0
4/6	0	0	0	0	0	0	0	0	0	0	0	0
11/6	0	0	0	0	0	0	0.7	0	0	0	0	0
19/6	0	0	0.1	0	0	0	0	0.1	0.2	0.3	0	0
26/6	0	0.2	0	0	0	0	0	0.3	0	0.3	0	0
4/7	0	0	0	0	0	0	0	0	0	0	0	0
8/7	0.2	0	0.1	0.7	0	0.1	1.2	0	1.2	0	0	0

Table 31 shows very little ladybird beetle activity and this is due to the low aphid numbers found in this trial. From other observations these beetles are found throughout the plant whenever aphids are present.

Table 32. Lacewing numbers found in the different sections of capsicum plants.

Date	Whole plant sample. Average number per plant											
	Bottom			Middle			Top			Throat		
	Egg	Larvae	Adults	Egg	Larvae	Adults	Egg	Larvae	Adults	Egg	Larvae	Adults
24/5	0	0	0	0	0	0	0	0	0	0	0	0
29/5	0	0	0	0	0	0	0	0	0	0	0	0
4/6	0.05	0	0	0	0	0	0	0	0	0	0	0
11/6	0	0	0	0	0	0	0.1	0	0	0	0	0
19/6	0.4	0.1	0	0.1	0	0	0.2	0	0	0	0	0
26/6		0	0.1	0.1	0	0	0.4	0	0.1	0	0	0
4/7	0.1	0.2	0	0.4	0	0	0.1	0.1	0	0	0	0
8/7	1.0	0	0	0.6	0	0	0.4	0	0	0	0	0

With ladybird beetles and lacewings, the eggs do not have any effect on the insect pests. These counts indicate the health of beneficial insect populations in situations where pest species are active.

Figure 15 shows the relationship of ladybird beetles and lacewings to the aphid populations in this trial. Only the adult, larval or nymph stages are included in the beneficial insect numbers. The ladybird beetle numbers increase as the aphid populations increase.

Figure 15. Relationship of ladybird beetles and lacewings to aphid populations.

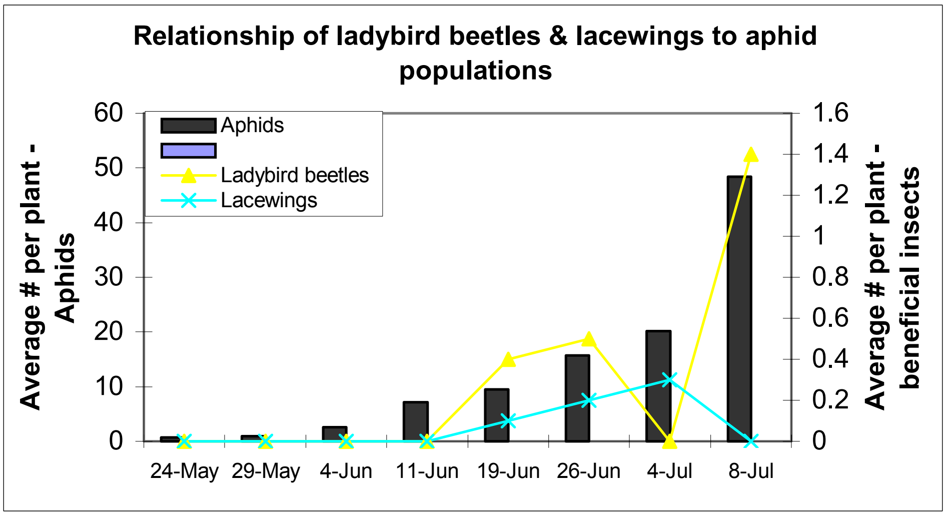


Table 33 shows the number of spiders and the average number of predatory bugs per plant found in the different sections of the capsicum plant.

Table 33. Average number of spiders and predatory bugs per plant found in the different sections of capsicum plants.

Date	Spiders				Predatory bugs
	Bottom 1/3	Middle 1/3	Top 1/3	Throat	
24/5	0	0.1	0.3	0.1	0
29/5	0	0	0.3	0	0.1
4/6	0.4	0.1	0.3	0.2	0
11/6	0.9	0.2	0.7	0	0.2
19/6	0.8	0	0.5	0	0
26/6	0.3	0	0.9	0	0
4/7	0.4	0.1	0.6	0	0
8/7	0.4	0	0.9	0	0

Table 33 shows that the spiders were active throughout all sections of the plant. This is due to the hunting nature of most of the species found, where they are continually moving, hunting for prey and not sedentary species that trap their prey through building webs.

With no aphid parasites recorded in these samples, they would be collected in the same sections of the plant as the aphids, but whether they attack the aphids in one section of the plant more than the other sections is unknown.

B. Sub-sampling

The number of Heliothis eggs and larvae recorded by the sub-sampling method and from whole plant sampling are given in Table 34. This sub-sampling method concentrates on leaf inspections and does not include the flowers or fruit. When larvae are detected it is probably when they are moving through the plant seeking flowers or fruit. Leaf inspections detect eggs and predictions on larval numbers are made based on these egg counts.

In determining larval numbers, the presence of egg parasites needs to be considered. The parasitism levels in eggs can reach over 90% and with this level of parasitism the number of larvae that will develop in the crop is reduced.

Table 34 also gives the parasitism levels recorded from the Heliothis eggs collected from the trial site and the number of moths collected from the pheromone traps.

Table 34. Number of Heliothis eggs and larvae recorded from sub-sampling and whole plant sampling methods. Pheromone trap catches of moths and egg parasitism levels are also shown.

Date	Pheromone trap, moth numbers	Sub-sample. Average number per plant		Whole plant sample. Average number per plant		Parasitism%
		Eggs	Larvae	Eggs	Larvae	
24/5	0	0	0	0.6	0	67
29/5	1	0.1	0	0.6	0	60
4/6	4	0	0	1.8	0.1	39
11/6	6	0.1	0	0.8	0.1	63
19/6	4	0.05	0	0.8	0	33
26/6	6			0.4	0	20
4/7	7	0.1	0	0.7	0	12.5
8/7	7			0.6	0	0

Table 34 shows very little relationship between moth numbers taken from the pheromone trap to the number of eggs detected in sampling. The data on pheromone trapping show that there were peak numbers in July, but very few in the months previous to then. This may indicate why very few eggs were recorded in this trial.

The parasitism levels recorded from the egg collections were high throughout most of the recording period, and this could explain the low number of Heliothis larvae being found in either of the two sampling methods.

Table 34 also shows the number of Heliothis eggs detected through sub-sampling is comparable to sampling the whole plant.

Table 35 gives the number of aphids recorded from sub-sampling and from whole plant sampling. This excludes the throat area as no leaves are in this section.

Table 35. Aphid numbers per plant by two sampling methods.

Date	Sub-sample. Average per plant	Whole plant sample. Average number per plant.
24/5	0	0.7
29/5	0	0.9
4/6	0.1	2.6
11/6	0.6	7.1
19/6	0.75	9.5
26/6		15.7
4/7	0.3	20.1
8/7		48.4

Table 35 shows that aphids were detected in the sub-sampling method and in the whole plant sampling method.

From the whole plant sampling, Table 35 shows that most of the aphid activity is in the top part of the plant, and this top and middle sections of the plant are the most likely sections to be checked in the sub-sampling method. The sub-sampling method is considered adequate to detect aphid populations.

Table 36 gives the average number of thrips per plant recorded from sub-sampling and from whole plant sampling.

Table 36. Average numbers of thrips per plant by two sampling methods.

Date	Sub-sample. Average per plant	Whole plant sample. Average number per plant
24/5	0	1.1
29/5	0	1.3
4/6	0	4.1
11/6	0	2.8
19/6	0	2.2
26/6		1.9
4/7	0.05	1.7
8/7		0.6

Table 36 shows that the sub-sampling method is not effective in detecting thrips populations. Thrips tend to be very active, concentrated around the flowers and move readily when disturbed. In sampling for Thrips it is recommended that flower samples be taken as well.

Table 37 gives the average number of silverleaf whitefly per plant recorded from sub-sampling and from whole plant sampling.

Table 37. Average numbers of silverleaf whitefly per plant by two sampling methods.

Date	Sub-sample. Average per plant	Whole plant sample. Average number per plant
24/5	0	0.2
29/5	0.35	0.1
4/6	3.0	1.0
11/6	0.85	0.4
19/6	1.55	1.5
26/6		0.3
4/7	5.5	0.4
8/7		1.5

Table 37 shows that the numbers of SLWF detected by the sub-sampling method is effective.

Table 38 gives the average number of the other insect species found per plant in sub-sampling of the plant and whole plant sampling. As mentioned in the whole plant sampling these populations were all low and this is reflected in the numbers recorded from the sub-sampling method.

Table 38. Populations of vegetable jassid, mites, cluster caterpillar and crickets detected in the two sampling methods.

Date	Sub-sample. Average per plant					Whole plant sample. Average number per plant			
	Jassids	Mites	Cluster	Crickets		Jassids	Mites	Cluster	Crickets
24/5	0	0	0	0		0.4	0	0	0
29/5	0	0	0.05	0		0.2	0	0	0
4/6	0.05	0	0.05	0		0	0.1	0.2	0
11/6	0	0	0	0.05		0.6	0	0	0
19/6	0	0	0	0		0	14.4	0	0
26/6						0	0.6	0	0.2
4/7	0	0	0	0.05		0	0	0	0.1
8/7						0.5	0.2	0	0.5

Table 38 shows that mites are the only group of insects that the sub-sampling method did not detect. The detection of most insect groups by the sub-sampling method shows its effectiveness in detecting most of the insect groups on the plants in the field.

Table 39 gives the average number of ladybird beetles, lacewings, spiders and aphid parasites detected per plant through the two sampling methods. The numbers do not include the egg stage for ladybird beetles and lacewings.

Table 39. Number of ladybird beetles, lacewings, spiders and aphid parasites detected in the plants through the two sampling methods.

	Sub-sample. Average per plant					Whole plant sample. Average number per plant			
Date	Ladybird beetles	Lacewings	Spiders	Aphid parasites		Ladybird beetles	Lacewings	Spiders	Aphid parasites
24/5	0	0	0	0		0	0	0.5	0
29/5	0	0	0	0.05		0	0	0.3	0
4/6	0	0	0.05	0		0	0	1.0	0
11/6	0	0	0.15	0		0	0	1.8	0
19/6	0.05	0	0.25	0		0.4	0.1	1.3	0
26/6						0.5	0.2	1.2	0
4/7	0.15	0	0.2	0		0	0.3	1.0	0
8/7						1.4	0	1.3	0

Table 39 shows that lacewings in the sub-sampling and aphid parasites in the whole of plant samples were not detected.

Table 40 gives the predatory bugs, mantids and other wasps recorded from the two sampling methods.

Table 40. Other beneficial insects recorded from the 2 sampling methods.

Date	Predatory bugs		Mantids		Other wasps	
	Sub-sample	Whole plant	Sub-sample	Whole plant	Sub-sample	Whole plant
24/5	0	0	0	0	0	0
29/5	0	0.1	0	0	0	0
4/6	0	0	0.05	0	0	0
11/6	0	0.2	0	0	0	0
19/6	0	0	0	0	0.05	0
26/6		0		0		0
4/7	0	0	0	0	0.1	0
8/7		0		0		0

Table 40 shows that predatory bugs were detected in the whole plant sampling but not by the sub-sampling method. Mantids and other wasps were not recorded in the whole plant samples but were detected by the sub-sampling method. This is probably due to low numbers.

Section 4 - Commercial crop studies

2002.

Table 41 gives the average number of Heliothis, aphids, thrips and silverleaf whitefly per plant for three separate crops.

Table 41. Average number per plant of Heliothis (Hel), aphids (Aph) thrips (Thr) and silverleaf whitefly (SLWF) recorded on 3 separate capsicum crops.

Date	Old crop					Younger crop					Youngest crop				
	Hel.		Aph	Thr	SLWF	Hel.		Aph	Thr	SLWF	Hel.		Aph	Thr	SLWF
	Eggs	Larvae				Eggs	Larvae				Eggs	Larvae			
17/4				0.05	0.25										
24/4					0.4	0.05									
30/4	0.35					0.4		0.1							
9/5		0.05	0.1		0.2	0.3				0.05					
22/5						0.05		0.05		0.15	0.15		0.05		0.05
29/5						0.1				0.3	0.2				0.15
6/6											0.35				0
13/6											0.15				0.2
19/6											0.15		0.05		0.05

Table 41 shows that the numbers of insect pests recorded in the 3 crops are low with the highest average number of Heliothis eggs recorded per plant being 0.4 eggs on the 30th April in the 2nd crop. It also shows that the number of eggs detected was higher in the two younger crops compared to the fruiting crop.

Table 42 gives the average number per plant of beneficial insects recorded from the same leaves. The numbers shown for the ladybird beetles and lacewings only includes the predatory stages of these insects.

Table 42. Average number per plant of beneficial insects recorded on three separate capsicum crops.

Date	Old crop				Younger crop				Youngest crop			
	Ladybird beetles	Lacewings	Aphid parasites	Spiders	Ladybird beetles	Lacewings	Aphid parasites	Spiders	Ladybird beetles	Lacewings	Aphid parasites	Spiders
17/4							0.1					
24/4			0.05				0.05					
30/4			0.1				0.2					
9/5				0.05			0.1					
22/5			0.05								0.05	0.05
29/5												
6/6												
13/6											0.05	
19/6												0.05

Table 42 shows very low numbers of beneficial insects. This could be attributed to the application of insecticides, through both direct effects on them and by reducing the pest populations as their food. It is interesting to note that some aphid parasites were recorded in the sprayed crops. Sampling from a second commercial grower in the same area who did apply regular insecticides showed very little insect activity in that capsicum crop. This crop was selected because it was to show the effects of being treated regularly with insecticides compared to the other crop that was not being sprayed.

The insects recorded from this crop are given in Table 43.

Table 43. Average number per plant of insect pests recorded on leaves from a sprayed capsicum crop.

Date	Heliothis		Aphids	SLWF
	Eggs	Larvae		
19/6			0.05	0.05
26/6				
4/7	0.01			0.05

Table 43 shows the low number of insects recorded. These numbers may reflect the effect of insecticides on insects within the crop whether they are pests or beneficial insects.

Figures 16 & 17 give the monthly total number of *Helicoverpa armigera* and *H. punctigera* moths collected from the pheromone traps for the 2 sites.

Figure 16. Number of *H. armigera* moths taken per month from pheromone traps.

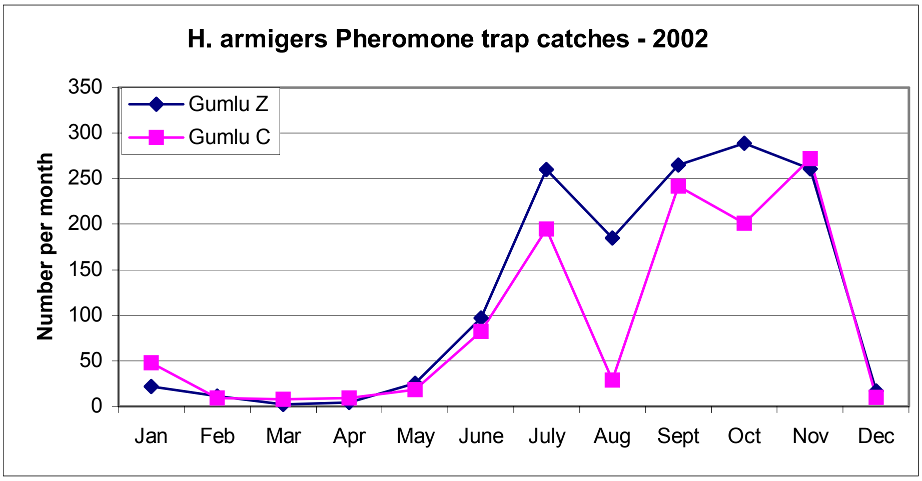


Figure 16 shows the numbers of moths collected were similar at both sites. The low number of moths collected in August at the Gumlu C site was due to frogs gaining access to the traps and eating some of the moths.

Figure 17. Number of *H. punctigera* moths taken per month from pheromone traps.

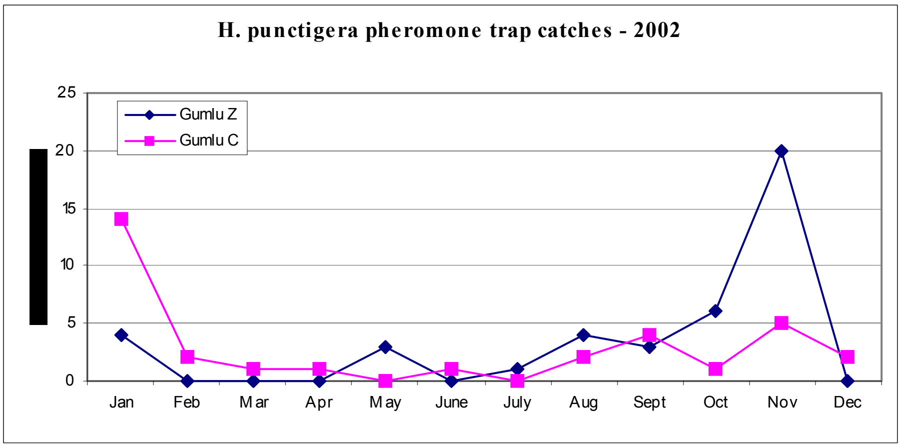


Figure 17 shows the low numbers of moths collected during the trial period. This species is not considered a pest at this time of the year and numbers do not approach those of the other species.

2003 (a).
Table 44 shows the number of insect pests recorded on 50 plants between March and June. The numbers of cluster caterpillar egg and larval stages are also given, as are the insecticides applied. Heliothis results are given separately in Figure 18.

Table 44. Average number of the insect pests per plant recorded off capsicums.

Date	Aphid	Cluster caterpillar		Jassids	Mites	SLWF	GVB	Chemical sprays
		Eggs	Larvae					
19/3	0.22		0.14	0.14	0.06	0.8		Dipel
24/3			0.08	0.1	0.02	0.6		
27/3		0.02	0.1	0.08		0.22		
31/3		0.04	0.1	0.06	0.02	0.5		
¾		0.04	0.02	0.02		0.64		
7/4		0.02				0.26		Dipel
10/4						1.06		
14/4				0.12		1.02		
17/4		0.02		0.04		0.72		Dipel
21/4		0.02	0.01			0.72		
24/4			0.02	0.08		0.58		
28/4		0.02	0.06	0.06		0.62		
1/5	0.02		0.1	0.06		0.74	0.04	NPV
6/5						0.22		
8/5			0.02	0.08		0.88		
12/5	0.02			0.02		0.46	0.02	
15/5	0.08			0.02	0.02	0.24	0.04	
19/5	0.04					0.3	0.1	
22/5						0.32	0.02	
26/5				.02		0.38	0.16	
29/5			0.02	0.04		0.22	0.06	Diptrex
2/6				0.06	0.02	0.46	0.02	

Table 44 shows that cluster caterpillar populations were detected through this crop. The populations caused leaf damage and this damage was visible when the crop was viewed from outside of the crop. Control with a biological insecticide was undertaken and observations noted that this insecticide controlled small and medium sized larva but not the larger larva. Some fruit damage by this insect was also noted. In most years this insect is not considered a pest.

Table 44 also shows that there was very little aphid activity, while jassids and SLWF numbers were recorded on most sampling dates. Green vegetable bug numbers increased in the later stages of the crop. This insect required controlling in the later stages of the crop.

Figure 18 shows the relationship of the average number of Heliothis eggs to the average number of larvae that were detected.

Figure 18. Relationship of egg numbers to larvae found.

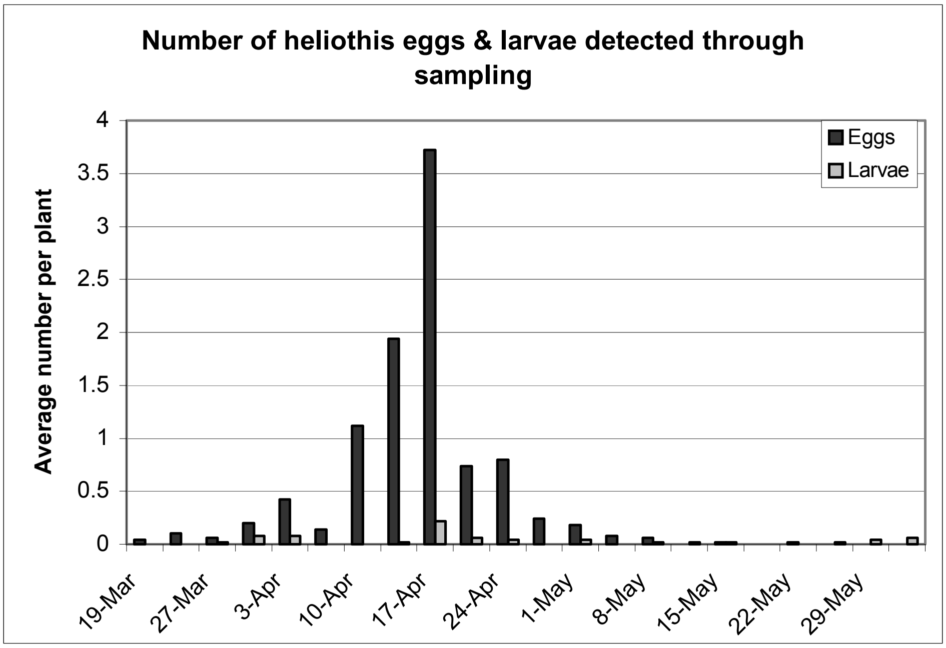


Figure 18 shows that one larva in 50 plants (0.02 per plant) was detected on the 27th March and the average number of eggs counted per plant 5 days prior of that sample was 0.072. The next 4 larvae detected in 50 plants (0.08) on the 31st March and again on the 3rd April had an average of 0.068 and 0.066 eggs detected per plant. This equates to 3.6, 0.85 and 0.825 eggs per plant before a larva would be detected.

The detection of approximately 1 egg per plant before a larvae is found is consistent with other results with low populations. As the egg population increased during April, 38 and 7 eggs per plant were detected before 1 larva per plant was found.

The sprays applied would not have had an effect on the larval numbers emerging.

As few larvae were being detected by the sub-sampling method during these high egg counts, two plants were collected from the field and examined in the laboratory. The numbers of eggs counted per plant were 31 and 36 respectively for each plant and no larvae were found.

Comparing the average number of eggs counted on the whole plant samples (33.5) with the average number detected in the leaf samples (1.94) during the same period, is approximately 17 times fewer eggs detected in the latter. This is close to the same result, which compared these two methods previously when the difference was approximately 13 times fewer in the leaf samples.

Egg collections were made from the field to determine egg parasitism levels. These are given Table 45.

Table 45. Number of eggs collected with parasitism levels.

Date	Number of Eggs collected	% parasitised	% of eggs that didn't emerge
14/4	210	69.5	10
24/4	78	55.1	27

Table 45 shows that the level of egg parasitism is high and this could account for some of the larvae not being found in the crop. This level of parasitism accounts for an average of 2.6 eggs per plant with an average of 3.75 eggs per plant being recorded.

Figure 19 shows the average number of thrips recorded in the whole plant samples taken on the 14th April, the average number of thrips per flower recorded from flower samples and the average number per plant from the leaf samples. On most of the sampling dates, 5 flowers were taken and on the following dates 10 flowers were taken, 7th ;14th ;24th and 28th April and 1st ;6th and 8th May.

Figure 19. Thrips detected on leaf, whole plant and in flower samples.

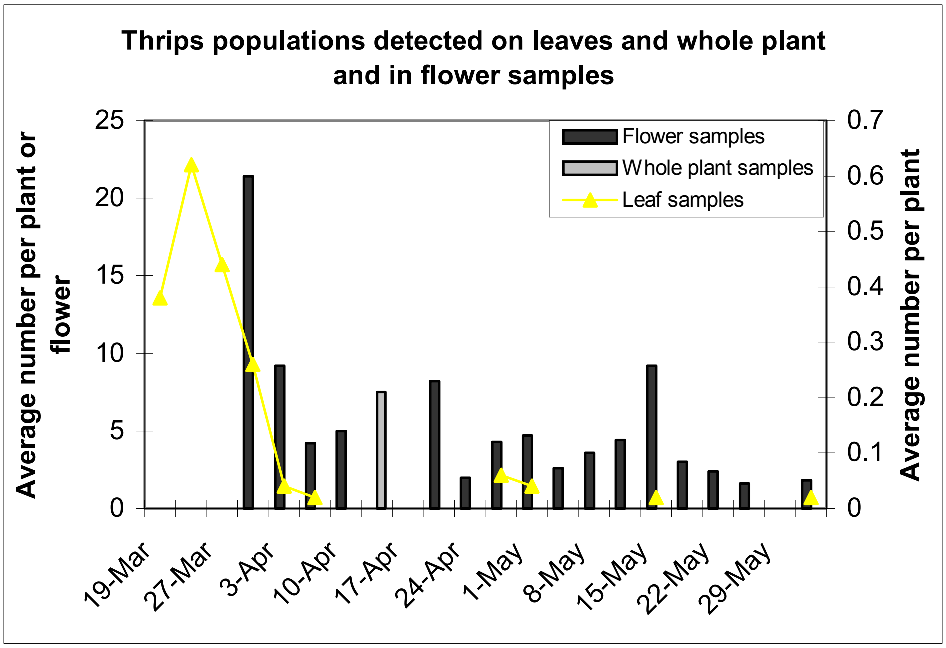


Figure 19 show that the leaf samples do not indicate the thrips numbers. From the one date where the whole plant sample was taken, the average number of thrips per plant is similar to the average number counted in the flower samples. This shows that flower samples are a good way to monitor thrips populations.

Beneficial insects

Table 46 gives the average numbers of beneficial insects per plant. The numbers for ladybird beetles and lacewings includes the predatory stages only. Observations indicate that when aphid parasites are present the aphid populations fell rapidly. As shown in Table 44, the aphid populations did not develop. With low populations of aphids it is expected that the other beneficial insects that feed on aphids, mainly ladybird beetles and lacewings will be scarce also.

Table 46. Average number per plant of beneficial insects recorded.

Date	Ladybird beetles	Lacewings	Mummies	Brown mired	Broken back bug	Spiders
19/3						0.06
24/3	0.02					0.04
27/3			0.14	0.06		0.08
31/3			0.06	0.06		0.08
3/4			0.04			0.02
7/4						0.04
10/4			0.04			
14/4		0.08				0.04
17/4		0.04	0.02		0.06	0.08
21/4		0.02	0.04		0.04	0.02
24/4			0.14	0.02		0.02
28/4		0.06	0.02	0.02		
1/5	0.04	0.08	0.02			
6/5		0.02				
8/5		0.04				
12/5						0.12
15/5				0.02		0.12
19/5				0.02		0.08
22/5		0.04				0.04
26/5		0.02				0.08
29/5						
2/6		0.02		0.02		0.06

Table 46 shows the consistent recording of spiders is probably due to the nil effect of insecticides. Even though insecticides were applied they were biological types and specific to Lepidopteran species. Lacewing numbers were present throughout the trial and they may have contributed to reducing Heliothis numbers.

Fruit samples

Table 47 gives the results of sampling fruit from both the trial site and from the crop adjacent to this site. Private consultants undertook monitoring of this adjacent crop for insects. During the sampling of the trial site the adjacent crop was sprayed up to 7 more times than the trial site with a range of insecticides including broad-spectrum insecticides. This was understandable as the Heliothis egg populations were high in these crops.

Fruit were colour graded and sized as leaf damage to the crop by cluster caterpillar caused sunburning of the fruit through being unprotected by the leaves.

Table 47. Average number of fruit harvested of 5 metres of row.

Site	Large fruit undamaged		Medium fruit undamaged		Damaged fruit by:	
	Red	Green	Red	Green	Insects	Sunburn
IPM	5.6	12.4	0.4	7.2	5	3.0
BCM	6.2	19.6	0.6	9.6	0.8	1.8

Analysis of the data showed no statistical difference between the trial block and the block being monitored. The monitored crop produced less damaged fruit. The insecticides probably contributed to this by reducing the leaf loss through controlling cluster caterpillar. The cost of these insecticides and their application needs to be considered in developing threshold levels.

2003 (b).
Table 48 gives the average number of Heliothis recorded per plant from the sprayed and unsprayed blocks.

Table 48. Average number per plant of Heliothis eggs and larvae recorded on 50 plants.

Date	Heliothis			
	Sprayed blocks		Unsprayed blocks	
	Eggs	Larvae	Eggs	Larvae
16/6	0.12	0.02		
23/6	0.12		0.08	
30/6	0.24		0.12	
7/7	0.26		0.04	0.04
14/7	0.04		0.2	0.02
21/7	0.18		0.02	
28/7	0.24		0.08	
4/8	0.04		0.08	
12/8				
18/8			0.08	0.02
25/8			0.02	
1/9				
8/9				
15/9	0.02			

Table 48 shows the Heliothis population did not reach a level where insecticides were required. As shown in other trials, the number of larvae recorded from the number of eggs detected is low. Following the harvest of this crop the comment from the grower was that it was a very good crop with very little fruit damage caused by insects.

The numbers of moths collected in the pheromone traps for both species of Heliothis are given in Figure 20.

Figure 20. Pheromone trap catches of Heliothis moths 2003.

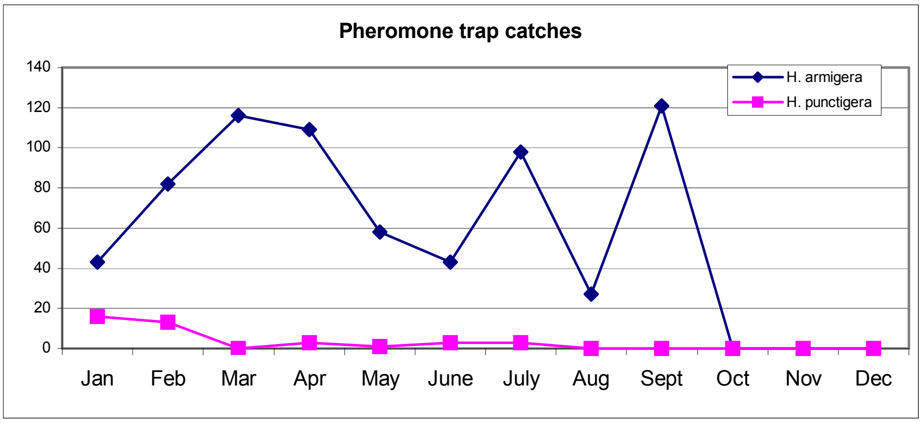


Figure 20 shows the number of *Helicoverpa punctigera* moths collected is very low and *H. armigera* averaging 70 moths per month during the period of the sampling.

Table 49 gives the average number per plant of other insect pests recorded from the sprayed and unsprayed blocks. Table 49 shows that the aphid populations were increasing and reached levels where the honeydew produced from them was starting to cause sooty mould development on the plant. The populations of aphids were higher in the sprayed blocks compared to the unsprayed blocks.

Table 49. Average number per plant of other insect pests in sprayed and unsprayed blocks of capsicum.

Date	Sprayed blocks					Unsprayed				
	Aphid	Thrips	Jassids	SLWF	GVB	Aphid	Thrips	Jassids	SLWF	GVB
16/6		0.02		0.02		0.02				
23/6	0.02		0.04	0.1				0.02	0.32	
30/6		0.06		0.18					0.54	
7/7	0.02	0.04		0.08		0.04	0.04		0.54	
14/7	0.02			0.04					0.3	
21/7	0.28			0.02					0.12	
28/7	0.22					0.02				
4/8	1.76	0.02		0.02		0.02			0.06	
12/8	23.26			0.34		0.56			0.52	
18/8	37.02			0.32		1.36			0.44	
25/8	2.04			0.3	0.02	1.12			0.86	
1/9	0.06			0.24		0.62			0.86	
8/9				0.06						
15/9				1.54						

An insecticide application of Imidacloprid (Confidor) was recommended to control aphids on the 18th August. The need for this spray application was that the aphid populations were high and very few beneficial insects had been recorded.

Figure 21 shows the relationship of the beneficial insects and aphids. The beneficial insects were ladybird beetles, lacewings and the aphid parasites.

Figure 21. Relationship of aphids and beneficial insects in sprayed and unsprayed crops.

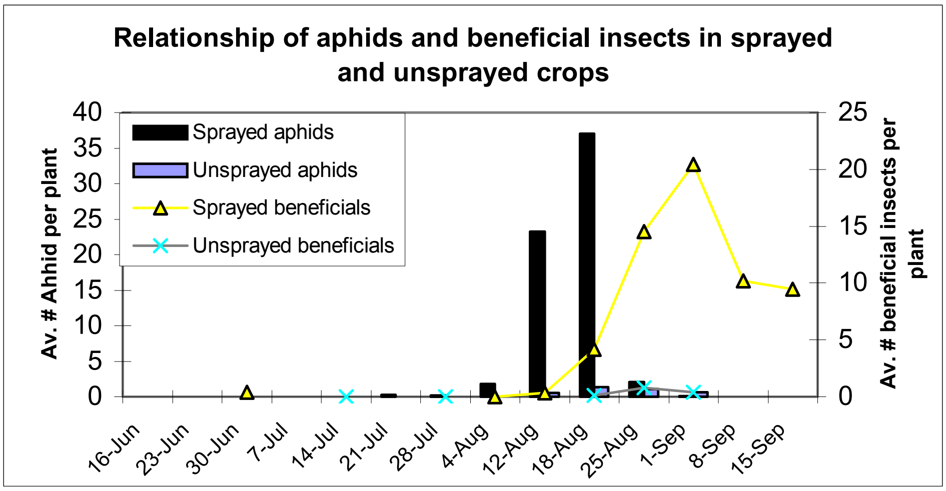


Figure 21 shows higher aphid populations in the sprayed blocks compared to the unsprayed blocks. It also shows the rapid decline in aphid populations when the aphid parasite is active. The number of parasites is much higher in the sprayed crop and this relates to the aphid populations.

Table 50 shows the average number of beneficial insects recorded in the sprayed and unsprayed blocks.

Table 50. Average number per plant of beneficial insects recorded in sprayed and unsprayed crops.

Date	Sprayed blocks					Unsprayed blocks				
	Ladybird beetles	Lacewings	Mummies	Broken back bug	Spiders	Ladybird beetles	Lacewings	Mummies	Broken back bug	Spiders
16/6										
23/6									0.02	
30/6	0.02	0.02			0.02					0.02
7/7										
14/7							0.02			
21/7					0.02					
28/7							0.02			
4/8		0.02								
12/8		0.1	0.26							
18/8			4.18					0.1		
25/8			14.54					0.8		
1/9			20.46					0.38		
8/9			10.18							
15/9			9.48		0.02					

Table 50 shows the low number of beneficial insects recorded in the crop until the aphid population increased, and then the very rapid decline due to the parasitic wasps.

Table 51 gives the thrips counts taken from both plant samples and flowers in the sprayed and unsprayed blocks.

Table 51. Average number of thrips per plant sample and average number per flower.

Date	Plant samples		Flower samples Av. Per flowers	Flower samples 5 flowers
	Sprayed block	Unsprayed block	Sprayed block	Unsprayed block
14/7			1.2	4.2
21/7			1.6	0.2
28/7			1.8	0.8
4/8	0.02		2.8	0.2
12/8			7.8	Nil sample
18/8			6.0	1.0
25/8			5.5	Nil sample
1/9			3.0	2.2
8/9			2.6	0.6
15/9			19.6	

Table 51 shows the failure of the leaf sampling to detect thrips populations compared to flower samples. It also shows the difference in thrips numbers between the sprayed and unsprayed crops. The reason for higher numbers in the sprayed crops is unknown.

2003 (c).
This trial compared the insects recorded from commercial crops in the Gumlu region with those from the Burdekin region over the same growing period.

Table 52 gives the average number per plant of insect pests recorded from the two regions. The numbers recorded in the Gumlu site are from an unsprayed crop. Thrips counts are from flowers.

Table 52. Average number per plant of insect pests recorded on crops from two growing regions.

Date	Gumlu		ARS		Gumlu	ARS	Gumlu	ARS	Gumlu	ARS	Gumlu	ARS
	Heliothis				Aphids		SLWF		GVB		Thrips	
	Eggs	Larvae	Eggs	Larvae								
21/7	0.08										0.2	
28/7	0.08		0.16		0.02	0.02					0.8	
4/8			0.28		0.02	0.56	0.06				0.2	
12/8	0.08	0.02	0.04		0.56	0.96	0.52				Nil sample	0.6
18/8	0.02		0.08		1.36	0.6	0.44				1.0	0.48
25/8					1.12	0.56	0.86			0.04	Nil sample	0.2
1/9					0.62		0.86			0.04	2.2	
8/9			0.04			0.04					0.6	0.44
15/9												

Table 52 shows more Heliothis eggs were recorded in the Ayr Research Station (ARS) crop than the commercial crop. Aphid numbers were similar except in the Gumlu crop the aphid parasites reduced the population. At the ARS site lacewings were responsible for reducing the aphid population.

Of the other insect pests recorded, thrips were common in flowers at both sites but higher in the commercial crop.

Figure 22 shows the relationship between aphids and beneficial insects.

Figure 22. Relationship between aphids, lacewings and parasitic wasps.

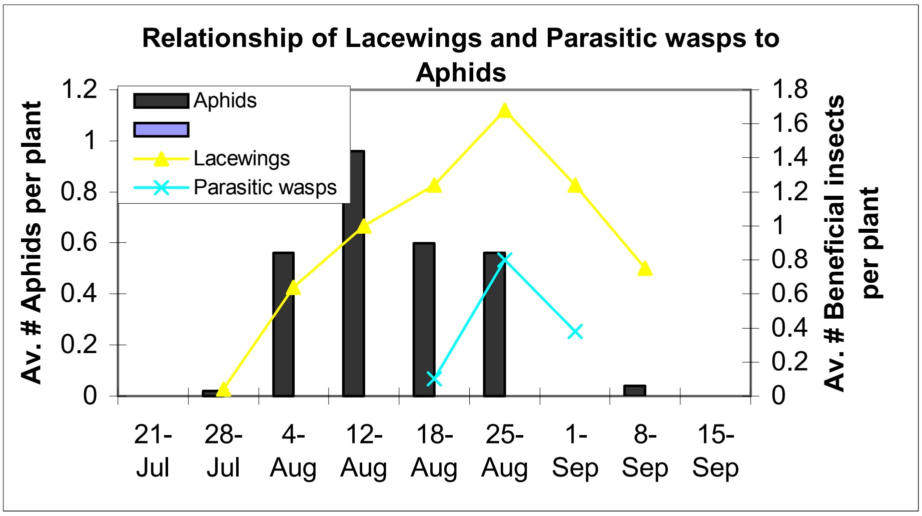


Table 53 gives the number of beneficial insects recorded on the plants for the 2 sites. Lacewings were the most common of the beneficial insects recorded.

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 (19th 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.

b. On the fruit but around the base of the fruit until it curved along its side.
c. Along the side of the fruit from the curve at the base to within 1/3rd of the fruit tip
d. The last 1/3rd of the fruit at the tip.

Pheromone traps were a Delta type, 15cm long with a rubber impregnated with pheromone as the lure, suspended from the top apex in the middle of the trap. A gel was smeared over the inside bottom of the trap to snare the moths attracted to the pheromone. Moths were recorded daily and removed.

In the following sub- sections, each block was divided into plots, 2 rows wide by 10 metres long. 1 (c) and 1 (e) were one row wide and all plots except 1 (e) were separated by one row lengthwise and two 2 rows in 1 (e). Chemical treatments were applied in water at the rate of 833L/ha and 750L/ha in 1 (e), all through a motorised knapsack sprayer.

Section 1 – Insecticide evaluations against all insect pests
Section 1 (a)
Two blocks of eggplant, each divided in half lengthwise and split into 5 plots, were marked out in each section. Insecticide sprays were applied weekly by tractor through a boom sprayer and there were 5 applications.

Two insecticides were evaluated for controlling eggfruit caterpillar and the trial design was randomised with 4 treatments replicated five times.
Treatments were:

A.	Control – nil sprays	
B.	Bt	Biological insecticide
C.	Bt	Biological insecticide
D.	Nitofol	580mls/L Methamidophos

Fruit samples were taken from 5 metre sections of row in each plot and 4 harvests were made to evaluate the treatments. Each fruit was inspected externally and also cut lengthwise into 4 sections to note larval presence or damage internally. Eggfruit caterpillar can enter very small fruit without leaving any damage to the outer surface of the fruit but when cut the damage is revealed.

Section 1 (b)
This trial evaluated 5 chemicals against a Nil spray treatment for the control of all insect pests. The trial design was 6 treatments replicated 3 times in a randomised block.

Treatments evaluated were:

A.	Avatar	400g/kg Indoxacarb	170g/ha
B.	Proclaim	50g/kg Emamectin benzolate	266mls/ha
C.	Gemstar +	Virus Biological insecticide	500mls/ha
	Amino-feed*		1L/ha
D.	Control		
E.	Sanmite	250g/L Pyribaden	800g/ha
F.	Rimon	100g/L Novaluron	500mls/ha

*Amino-feed contains a mixture of proteins, amino acids, reducing sugars and sucrose inverts. It attracts predatory insects and is recommended to use in IPM systems.

Sprays were applied on the 2nd the 22nd and 31st July, the 7th the 15th and 21st August and three evaluation periods were made. The first period measured the effect of the treatments applied on the 2nd July and included a pre-treatment count, and 3 and 7 day post treatment counts. The second and third evaluations were made on the 29th July and 5th August with a sample size of 2 leaves per plot.

Counts were made for eggfruit caterpillar on 30 fruit per treatment. Other insect numbers were recorded by examining 3 leaves per plot and counting the number of Heliothis, aphids and beneficial insects or through examining 30 flower buds per treatment for thrips.

Harvesting of fruit was undertaken on the 19th and 27th August and on the 5th September. Two fruit per plot were examined on the first date and mature fruit on the last two dates. Fruit were examined for damage and insects.

Section 1 (c)

This trial evaluated 2 chemicals against a Nil spray treatment for the control of SLWF. The trial design was 4 treatments replicated 3 times in a randomised block. Treatments evaluated were:

A.	Ark 22008	Experimental sample	1.0% concentration
B.	Ark 22008	Experimental sample	2.0% concentration
C.	Sanmite	250g/L Pyribaden	800g/ha
E.	Nil spray		

Evaluations of the treatment effects were made at 3, 13 and 15 days post-treatment by randomly selecting 5 leaves per plot and counting the honeydew drops.

Section 1 (d)

This trial evaluated 4 chemicals against a Nil spray treatment for the control of SLWF.

The trial design was 6 treatments replicated 3 times in a randomised block. Treatments evaluated were:

A.	Natrasoap	Insecticidal soap	2% concentration
B.	Ark 22008	Experimental product	1% concentration
C.	Confidor	200g/L Imidacloprid	300mls /ha
	+ D C Tron	839g/L Mineral oil	0.5% concentration
D.	D C Tron	839g/L Mineral oil	0.5% concentration
E.	D C Tron	839g/L Mineral oil	1.0% concentration
F.	Nil spray		

Evaluations of the treatment effects were made at 3, 7, 10 and 14 days post-treatment by randomly selecting 5 leaves per plot and counting honeydew drops.

Section 1 (e)

This spray trial evaluated 4 chemicals against a Nil spray treatment for the control of SLWF. The trial design was 6 treatments replicated 4 times in a randomised block.

Treatments evaluated were:

A.	Natrasoap	Insecticidal soap	2% concentration

B.	Ark 22008	Experimental product	1% concentration
C.	Confidor	200g/L Imidacloprid	300mls /ha
	+ D C Tron	839g/L Mineral oil	0.5% concentration
D.	Ark 22008	Experimental product	1% concentration
E.	Confidor	200g/L Imidacloprid	300mls /ha
	+ D C Tron	839g/L Mineral oil	0.5% concentration
F.	Nil spray		

Evaluations of the treatment effects were made at a pre-treatment count and a 7 day post treatment count by randomly selecting 5 leaves per plot and counting the honeydew drops.

To show the relationship of honeydew drops to the number of nymphs on a leaf, 30 leaves were collected and the nymphs on the leaf counted prior to placing the leaf in the plastic bag to record honeydew drops 2 days later.

Section 2 –Biology studies – eggfruit caterpillar
Pheromone trapping
Section 2 (a)
In each of two blocks of eggplant a pheromone trap was placed at each end at a height of 1 metre. Weekly moth catches were recorded and lures changed monthly.

To relate egg numbers detected on the fruit to pheromone moth catches, 50 fruit were collected weekly and examined in the laboratory and egg numbers recorded.

Section 2 (b)
Three trap sites, one in Gumlu and two in the Burdekin region, each over 10km kilometres apart, were set up in areas that had eggplant crops growing. Traps were checked regularly between 3 to 7 days and moth numbers recorded.

Section 2 (c)
In a commercial crop, 200m x 25 rows, 12 pheromone traps of the delta type were set up around the perimeter of the crop approximately 20 m apart. The position of trap numbers 1 to 6 ran down one side of the crop and position 7 to 12 along the other. This made position numbers 1 and 12, 2 and 11, etc to be opposite each other separated by 25 rows of crop. These traps were serviced and randomly rotated every 2 to 3 days and moth numbers recorded.

Section 2 (d)
In each of 2 blocks, 2 pheromone traps were placed at each end at a height of 1 metre. Weekly moth catches were recorded and lures changed monthly. In a commercial crop, 200m x 20 rows, 3 traps were set up with one trap at each end and 1 in the middle of the crop. Moth numbers were recorded weekly.

Field observations
Section 2 (e)
Fruit were examined to record where eggs were being laid in the four sections of the fruit and fruit stem.
The number of eggs laid on individual fruit was also recorded. Counts of egg numbers on the fruit were used to determine if they related to the larval numbers that

were found in the fruit. Two fruit samples, the first with 138 fruit and the second 74 fruit, were taken from the field and cut open to note larval numbers per fruit.

Egg and larval growth studies.
Section 2 (f)
Development of the egg through to emergence was recorded. Fruit were marked in the field and inspected daily to remove the freshly laid eggs (within 12 hours old) that were found. These eggs still attached to the fruit were held in the laboratory at 25^0 C. The eggs were inspected twice daily and the larval emergence recorded.

Adults were held in cages and fed a sugar solution in a cotton wad. Eggs were laid on the side of the container and these were removed daily. These eggs were check hourly to note emergence. One-hour old larvae were placed separately on individual pieces of eggplant fruit, approximately 5mm square. The pieces were previously dipped in a weak solution of citric acid to help stop oxidation of the fruit surface. These pieces were placed on filter paper in 9cm glass perti dish. Five sets of larvae were placed in each chamber of a multi- temperature incubator with a temperature range from 14^0C to 39^0C.

Section 3 – Commercial crop studies
Section 3 (a)
Thirty fruit samples were collected and examined. The position of the egg laid on the fruit and the number of larvae found in the fruit were recorded.

Section 3 (b)
Five leaves off 20 plants were examined for all insect species. Counts of honeydew drops were made for SLWF from 3 leaves, one in the top 1/3 of the plant, 1 in the middle area and 1 from the bottom 1/3 of the plant off 10 plants.

Section 3 (c)
Ten whole plants were examined to note location and presence of the insects on the plant.

Heliothis egg parasites were recorded by collecting field laid eggs.

RESULTS
Insecticide evaluations against all insect pests.
Section 1 (a)
Table 54 gives the average number of fruit harvested from the 4 picks for each treatment.

Table 54. Average number of good, damaged and total fruit harvested as well as the average number of eggfruit caterpillar larva per treatment.

Treatment	Good fruit	Damaged fruit	Total fruit	Larvae
Control	18.8^{ab}	6.0^{a}	24.8^{ab}	2.2^{a}
Bt	14.2^{a}	2.4^{a}	16.6^{a}	1.4^{a}
Bt	24.0^{bc}	4.4^{a}	28.4^{b}	3.2^{a}
Nitofol	31.4^{c}	11.0^{b}	42.4^{c}	7.0^{b}

Numbers followed by the same letter are not significantly different at the 5% level.

Table 54 shows that the Nitofol treatment and one of the Bt treatments (C) have significantly more good fruit than the other Bt treatment, and Nitofol had significantly more good fruit that the nil sprayed treatment. With the total number of fruit harvested it shows that the Nitofol treatment had significantly more fruit harvested than the other treatments, and that one of the Bt treatments (C) had more fruit harvested than the other Bt treatment.

The Nitofol treatment had significantly more damaged fruit than all of the other treatments, but also had significantly more eggfruit caterpillar larvae recorded from the fruit than the other treatments.

Section 1 (b)

Table 55 gives the average number of SLWF honeydew drops counted per leaf for the different treatments. A pre-treatment count and 3 and 7 day post-treatment counts are shown.

Table 55. Average number of honeydew drops per leaf.

Treatment	Pre-treatment	3 day post treatment	7 day post treatment
Avatar (A)	56.9	64^{ab}	73.0^{c}
Proclaim (B)	31.5	142^{bc}	35.4^{ab}
Gemstar + aminofeed (C)	44.2	121^{ab}	72.1^{bc}
Nil spray (D)	76.1	72^{ab}	32.3^{a}
Sanmite (E)	78.5	10^{a}	13.7^{a}
Rimon (F)	105.7	246^{c}	90.7^{c}

Numbers followed by the same letters are not significantly different at the 5% level.

Table 55 shows that there was no significant difference in the number of honeydew drops produced between the treatments at the pre treatment count. At the 3-day post treatment count, the Sanmite had significantly less drops than the Rimon and Proclaim treatments. The Control, Avatar and Gemstar with aminofeed had significantly less honeydew drops than the Rimon treatment.

At the 7-day post treatment count the Sanmite, Control and Proclaim treatments had significantly less honeydew drops produced than the Rimon and Avatar treatments. The Sanmite and Control treatments also had significantly less honeydew drops than the Gemstar with Aminofeed treatment.

Table 56 gives the average number of honeydew drops counted per leaf for the different treatments. The counts on the 29th August and 5th September were made 8 and 15 days after the last sprays was applied.

Table 56. Average number of honeydew drops per leaf.

Treatment	29th August	5th September
Avatar (A)	817	231
Proclaim (B)	694	174
Gemstar + aminofeed (C)	935	253
Nil spray (D)	520	80
Sanmite (E)	117	14
Rimon (F)	276	93

Table 56 shows that there were no significant differences between the treatments on these two dates.

Fruit was harvested over 3 picks and the results are given in Table 57. Two fruit per plot were harvested on the 19th and mature fruit on the 27th August and 5th September.

Table 57. Average number for 3 picks and total, in damaged fruit harvested and Heliothis per plot.

Treatment	Pick 1 – 19th		Pick 2 – 27th		Pick 3 – 5th		Total		
	Damaged	heliothis	Damaged	heliothis	Damaged	heliothis	Fruit	Damaged	heliothis
Avatar (A)	0.00	0.00	0.00	0.00	0.00[a]	0.00	32.3	0.00	0.00
Proclaim (B)	0.00	0.00	0.00	0.00	0.33[a]	0.00	34.3	0.33	0.00
Gemstar + Aminofeed (C)	0.00	0.33	2.67	0.33	1.00[a]	0.00	34.7	3.67	0.67
Control (D)	0.00	0.00	1.67	0.33	3.67[b]	0.67	30.7	5.33	1.00
Sanmite (E)	0.33	0.00	1.67	0.33	3.00[b]	0.67	25.3	5.00	1.00
Rimon (F)	0.00	0.00	1.00	0.67	0.67[a]	0.67	29.3	1.67	1.33

Numbers followed by the same letter are not significantly different at the 5% level.

Table 57 shows that at the 3rd pick the Control and Sanmite treatments had significantly more damaged fruit by Heliothis than the other treatments.

Table 58 gives the number of eggfruit caterpillar found on the fruit and the position on the fruit where they were found.

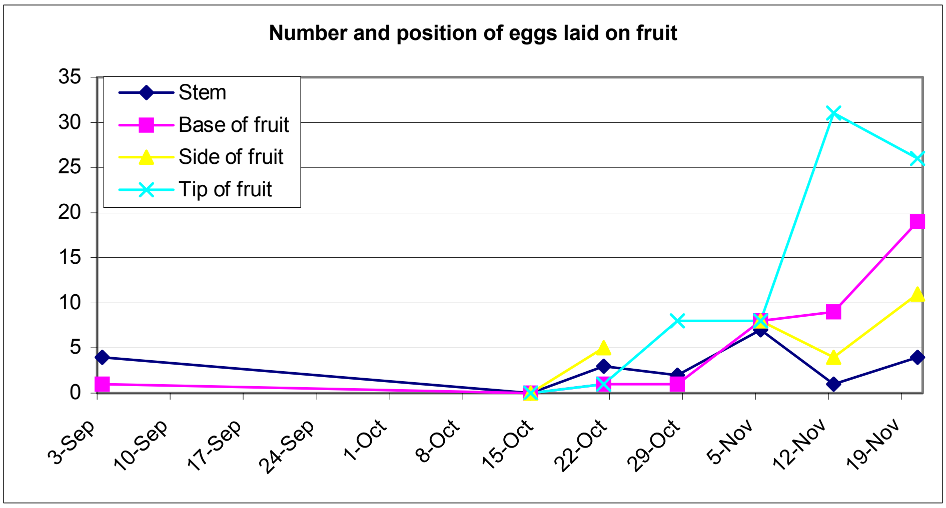
Table 58. Numbers of eggfruit caterpillar eggs and larvae found, and position on fruit.

Date	Position 1		Position 2		Position 3		Position 4	
	Egg	Larvae	Egg	Larvae	Egg	Larvae	Egg	Larvae
3/9	4		1					
14/10								1
21/10	3		1	1	5		1	4
28/10	2		1				8	
5/11	7		8		8		8	
12/11	1		9		4		31	
20/11	4		19		11		26	

Only 1 egg was found on the fruit during the spray period between the 6th to the 19th August in treatment E. This is not likely to have been due to the insecticides, as the Control plots did not record insect eggs or larvae. It could be that the Eggfruit caterpillar populations established after the spraying had ceased on the 21st August.

Table 58 shows that from the 3rd September the number of eggs laid on the fruit increased and the favoured area for ovipositing is on the tip of the fruit. This is illustrated in Figure 23.

Figure 23. Numbers of eggfruit caterpillar eggs and the position they are laid on the fruit.



The evaluation of the chemicals on Heliothis, aphids and thrips was undertaken on the 6th the 12th and the 19th August. These counts followed 3, 4 and 5 spray applications respectively. The average number of Heliothis and aphids recorded from 3 leaves per plot, and the number of thrips recorded from 10 flower buds per plot, are given in Table 59.

Table 59. Average numbers of pests recorded per leaf or per flower bud for 3 observation periods

Date	Treatment	Heliothis		Aphids	Thrips
		Eggs	Larvae		
6/8	**A**	0.33	0.07	2.13	6.20
	B	0.07		0.93	3.03
	C	0.40		0.53	3.57
	D	0.00	0.13	1.00	3.73
	E	0.33	0.27	0.07	3.73
	F	0.13	0.07	2.73	2.10
12/8	**A**	0.80	0.13	1.53	1.50
	B	0.53		0.60	2.03
	C	0.20	0.13	1.13	1.07
	D	0.13	0.07	0.80	2.50
	E	0.53	0.07	0.13	0.77
	F	0.27	0.13	8.53	0.47
19/8	**A**	0.27	0.07	0.93	2.10
	B	0.47		1.20	1.03
	C	0.13	0.07	1.40	0.97
	D	0.47	0.13	0.53	1.77
	E	0.67	0.20	0.47	1.03
	F	0.67		7.00	1.00

Analysis of the data shows that on the 6th August the Control, Proclaim and the Rimon treatments had lower Heliothis egg numbers than Gemstar + Aminofeed, Sanmite and the Avatar treatments. The counts on the 12th August showed that the Control, Gemstar + Aminofeed and Rimon treatments had lower numbers of Heliothis eggs than the Avatar, Proclaim and Sanmite treatments, and the Sanmite and Proclaim treatments also had lower numbers of eggs than the Avatar treatment.

The count on the 19th August showed the Gemstar + Aminofeed and Avatar treatments had lower numbers of Heliothis eggs than the Rimon and Sanmite treatments, and also the Gemstar + Aminofeed treatment had fewer eggs than the Control and Proclaim treatments.

For the Heliothis larval counts all of the treatments had lower numbers of larvae than the Sanmite treatment. The Gemstar + Aminofeed and Proclaim treatments also had lower numbers of larvae than the Control treatment. Counts on the 12th August showed that the Proclaim, Sanmite and Control treatments had fewer larvae than the Avatar, Gemstar + Aminofeed and Rimon treatments, and the Proclaim treatment had less larvae than the Control and Sanmite treatments. The counts on the 19th August showed that the Rimon, Proclaim, Avatar and Gemstar + Aminofeed treatments had fewer larvae than the Sanmite and Control treatments. Also the Rimon and Proclaim treatments had fewer larvae than the Gemstar + Aminofeed and Avatar treatments.

For Heliothis larvae, the numbers were low but Proclaim showed the best overall control.

For aphids, the count on the 6th August showed that the Sanmite, Gemstar + Aminofeed, Proclaim and the Control treatments had fewer aphids than the Rimon and Avatar treatments. On the 12th August count, all of the treatments had less aphids than the Rimon treatment and on the 19th August, all of the treatments had less Aphids than the Rimon treatment.

These data suggest that the Rimon treatment had increased aphid populations. This might have been due to the effect on beneficial insects, but the sampling showed low numbers of predators of aphids in the trial.

The thrips counts on the 6th August showed that all of the treatments had fewer thrips than the Avatar treatment and also that the Rimon treatment also had less thrips than the Control, Sanmite and Gemstar + Aminofeed treatments. The count on the 12th August showed that the Rimon, Sanmite and Gemstar+ Aminofeed treatments had lower numbers of thrips than the Control and Proclaim treatments. Also the Avatar treatment had fewer thrips than the Control. The Rimon treatment also had fewer thrips than the Avatar treatment. The count on the 19th August showed that the Gemstar + Aminofeed, Rimon, Sanmite and Proclaim treatments had lower numbers than the Avatar and Control treatments.

From these results, Rimon has some effect on thrips numbers.

Section 1 (c)
The number of honeydew drops produced by the SLWF showed no significant difference between treatments. Figure 24 shows the SLWF honeydew drops produced at the pre-treatment count and at 3, 7, 13 and 15-day post treatment counts.

Figure 24.   SLWF honeydew drops produced in 4 treatments.

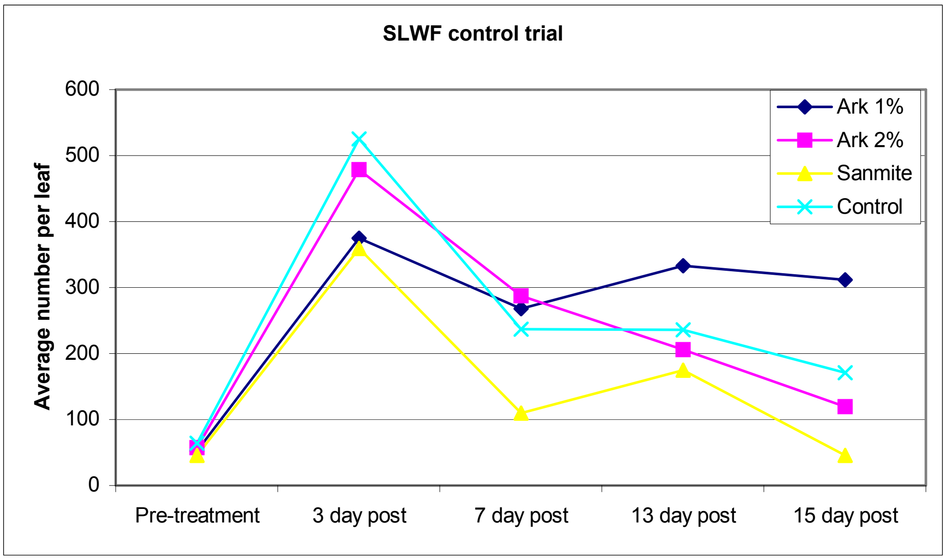


Figure 24 shows that the SLWF population, based on honeydew counts, increased from the pre-treatment count to the 3 day post treatment count, then declined in all treatments.   Sanmite had the biggest reduction in numbers 15 days post treatment, and the Ark (at 1%) the lowest decline in numbers during the same pereiod.

Section 1 (d)

The results from this trial did not show any significant differences between the treatments.   Figure 25 shows the effects of the different treatments on SLWF populations.

Figure 25.   SLWF honeydew counts, at pre and 3, 7, 10 and 14 day post treatment application.

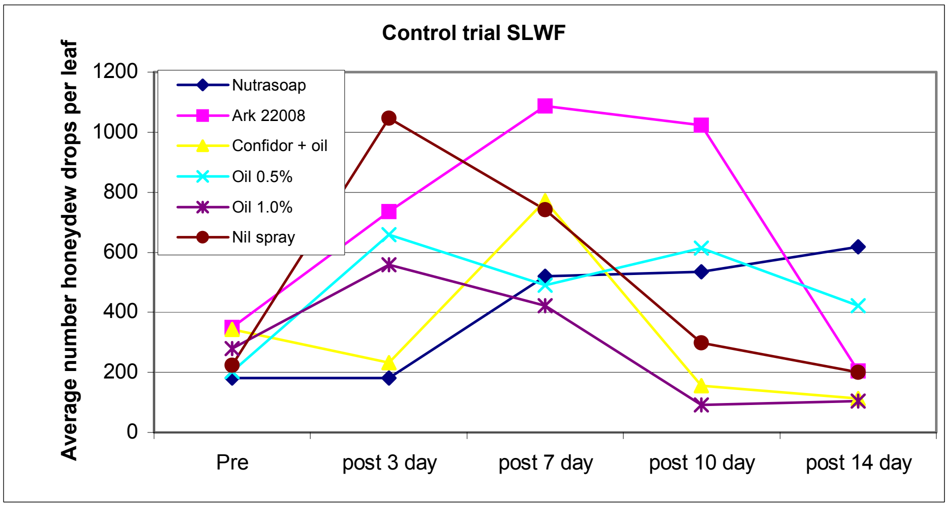


Figure 25 shows that the Natrasoap and Confidor plus oil treatments were the only products at the 3 day post treatment count to hold or reduce the number of honeydew drops produced by SLWF from that of the pre-treatment count.   This figure also shows that in the Nil sprayed treatment and the 2 oil concentration treatments, the honeydew drops decreased after the 3 day count.   All treatments except the Natrasoap had reduced honeydew drops by the 14-day post treatment count. Whether this is due to beneficial insects affecting SLWF populations is unknown, but previous studies have indicated that unsprayed populations will decline.

Section 1 (e)

Table 60 gives the number of honeydew drops produced by SLWF sprayed with insecticides.

Table 60. Average number per plot of honeydew drops produced.

Treatment	Pre count	Post count
Natrasoap (A)	299	2841[b]
Ark 22008 (B)	458	3243[b]
Confidor + oil (C)	274	484[a]
Ark 22008 (D)	453	3625[b]
Confidor + oil (E)	339	491[a]
Nil spray (F)	365	3165[b]

Numbers followed by the same letter are not significantly different at the 5% level.

Table 60 shows that both of the Confidor plus oil treatments (C & E) have significantly less honeydew drops produced that the other treatments.

Figure 26 shows the comparison between the number of honeydew drops and the actual number of SLWF nymphs on the leaf.

Figure 26. Comparison of honeydew drops and SLWF nymph count on the leaf.

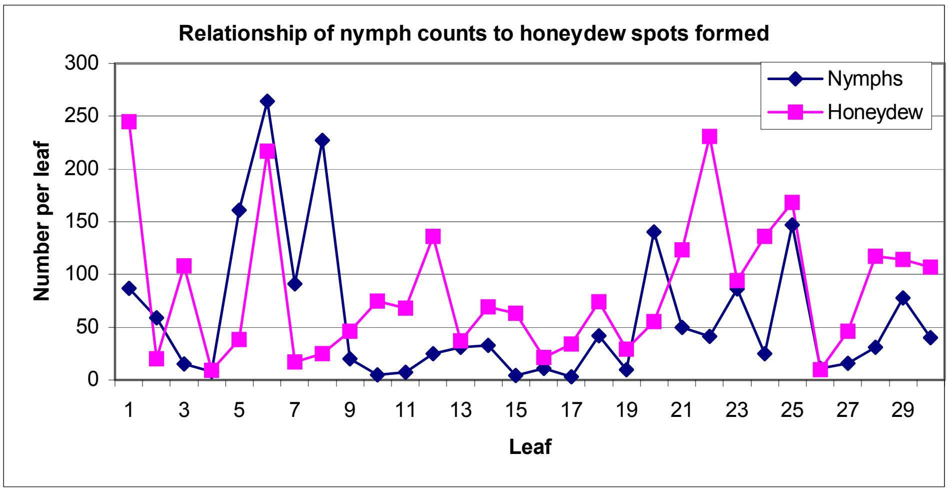


Figure 26 shows that the counts of nymphs and the number of honeydew drops produced are not consistent, suggesting that there could be errors in both of these methods. Honeydew drops are only produced from live insects, and the first nymphal stage is active before becoming stationary which could increase the number of drops. Also the inclusion of dead nymphs in the count prior to confirmation of death, could bias the actual insect counts.

Section 2 – Biology studies – eggfruit caterpillar
Pheromone trapping of eggfruit caterpillar moths.
Section 2 (a)

Figure 27 shows that an average of 12 moths were collected each week from both blocks. The moth numbers caught have high and low periods and this maybe due to the light (moon cycles) or fluctuations in the field populations. How far this moth will fly or the effect of light intensity on its flight activity is unknown.

Figure 27. Average weekly pheromone trap catches per eggplant block.

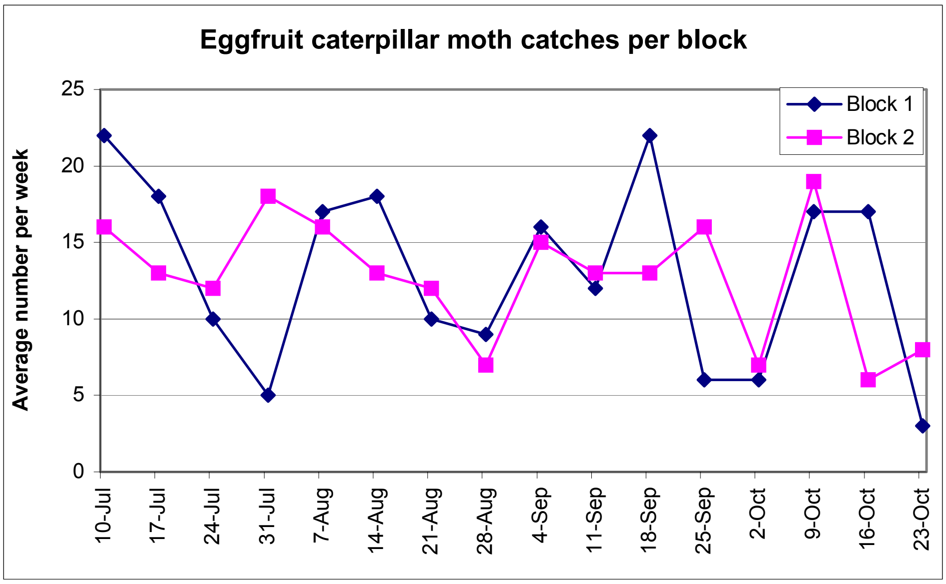


Figure 28 shows the number of eggs recorded on 50 fruit. Also the number of eggs recorded and the total number of moths taken from the pheromone traps is shown.

Figure 28. Weekly egg lays on 50 fruit and moths taken from pheromone traps.

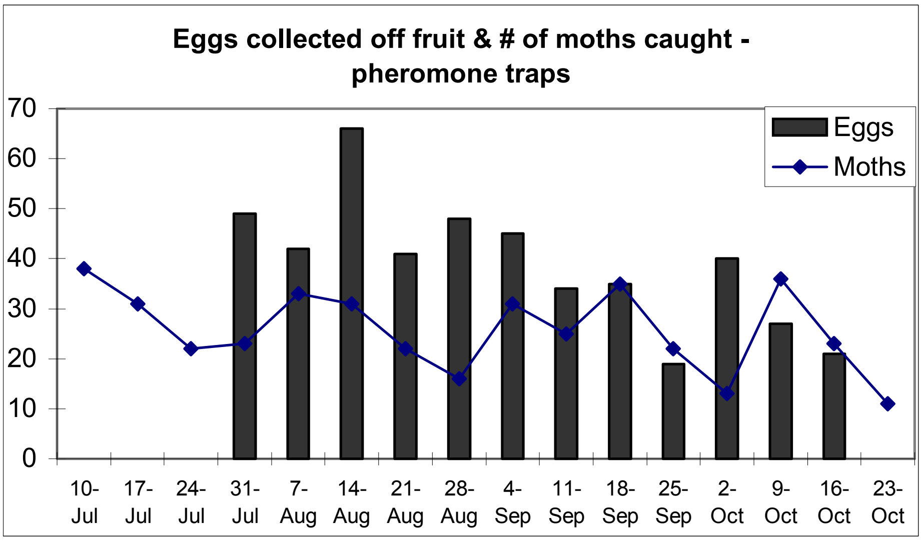


Figure 28 shows no clear relationship between the number of eggs laid and the number of moths taken from the traps. This could indicate that we cannot rely solely on the number of moths trapped to indicate the numbers of eggfruit caterpillar eggs laid. The gap in the figure for number of eggs between the 10^{th} and 31^{st} July is due to no fruit being checked on those dates.

Section 2 (b)

Figure 29 shows the average number of moths collected at the pheromone traps and the fluctuations in the flight patterns of the moths from 3 sites. The trapping period for each site covers the period from April to May with the Gumlu site being maintained until the end of July.

Figure 29. Average number of moths collected from pheromone traps at 3 sites.

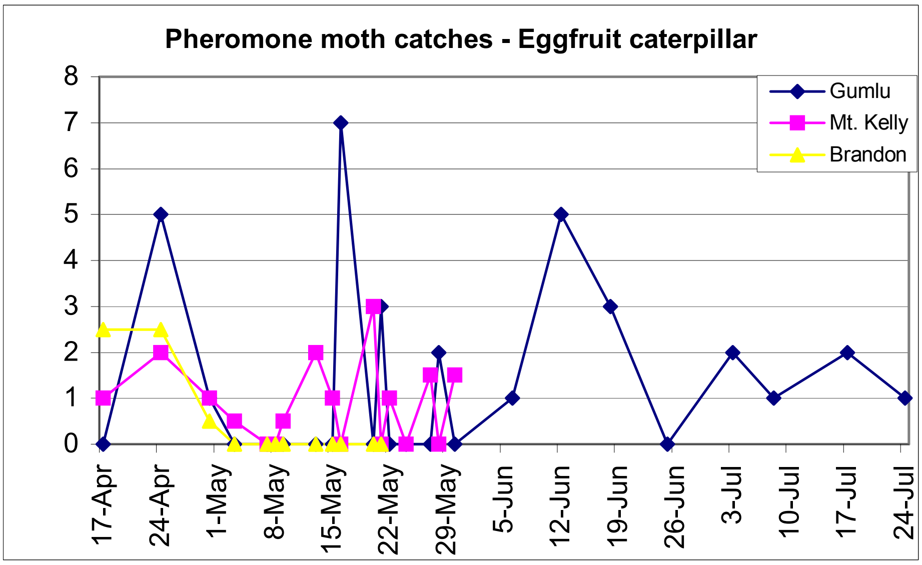


Figure 29 shows the population in the Gumlu region were higher than the other two sites. Why the numbers remained at 0 in the Brandon region is unknown as the crop was unsprayed.

Section 2 (c)

Table 61 gives the results for the number of moths caught in 12 pheromone traps. The number of moths trapped in each position has been analysed to note if there were hot spots within the crop. Analysis of the number of moths collected in each trap was also undertaken to determine if there was any variation in the lures.

Table 61. Average number of moths trapped between 7th May and 30th May.

Trap # or position	1	2	3	4	5	6	7	8	9	10	11	12
Trap	0.33^{abc}	0.11^{ab}	0.11^{ab}	0.33^{abc}	0.22^{ab}	0.78^{c}	0.56^{bc}	0.0^{a}	0.33^{abc}	0.56^{bc}	0.0^{a}	0.0^{a}
Position	0.22	0.33	0.67	0.44	0.22	0.22	0.11	0.0	0.56	0.22	0.0	0.33

Numbers followed by the same letter are not significant at the 5% level.

Analysis of the data shows that trap 6 caught significantly more moths that traps 2, 3, 5, 8, 11 and 12 and that traps 7 and 10 collected significantly more moths that traps 8, 11 and 12. The number of moths collected from the different traps may vary because the rubbers containing the pheromone are not uniform in size and the dose of pheromone applied to them can differ.

Analysis of the data on position of the traps showed no significant difference in the number of moths collected. This indicates that moths were active throughout the crop.

Section 2 (d)
Table 62 shows the total number of moths collected from the pheromone traps at Ayr between 3rd July and 4th December and Brandon 18th June and 23rd October. There were 3 traps at the Brandon site and 4 at the Ayr site.

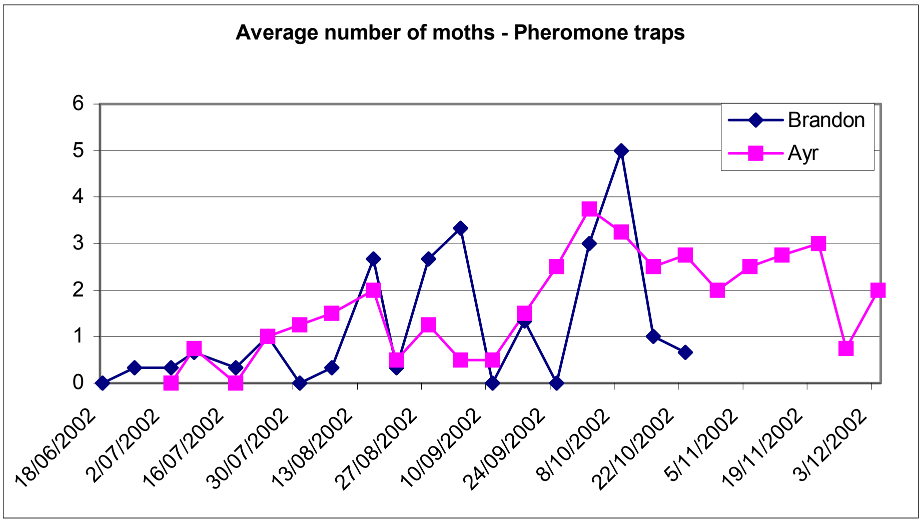
Table 62. Total number of eggfruit caterpillar moths caught at Brandon and Ayr.

Date	Brandon			Ayr			
	Trap number			Trap number			
	1	2	3	1	2	3	4
18/6 to 23/10	34	29	4				
3/7 to 4/12	0	1	0	32	28	50	42

Trap number 3 at Brandon caught lower numbers of moths than the others, but the reason is unknown as the traps were cleared weekly and the lures changed regularly.

Figure 30 shows the average number of moths caught at each site between the 18th June and 4th December, with most activity between August and December.

Figure 30. Average number of eggfruit caterpillar moths caught.



Field observations on eggfruit caterpillar
Section 2 (e)
Table 63 gives the percentage of fruit with eggs found on them from a sample of 50 fruit, and the percentage of eggs laid in the different positions on the fruit. Sampling of plants did not reveal any eggs being laid further back along the branches or leaves of the plant.

Table 63. Percentage of fruit with eggs and positions of eggs on fruit.

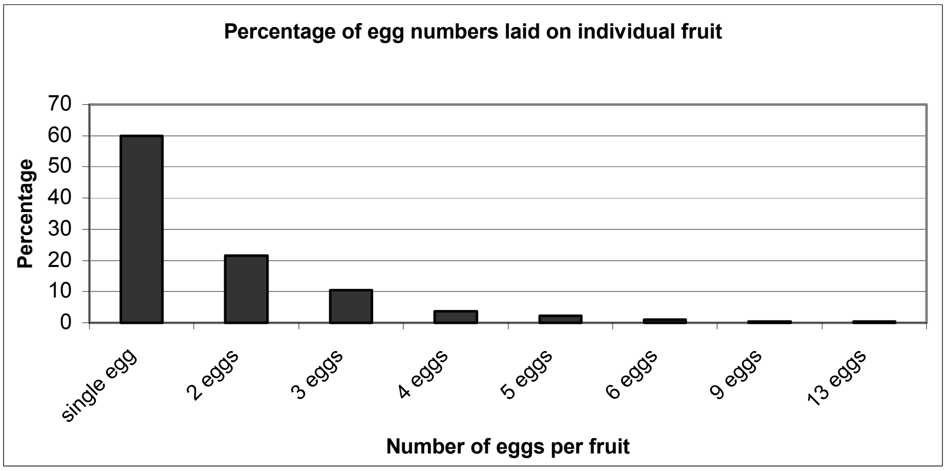
Date	% of fruit sampled with eggs	Percentage of eggs laid in different position on the fruit			
		Stem	Base of fruit	Side of fruit	Tip of fruit
2/8	50	10.2	34.7	53.1	2.0
14/8	48	9.5	11.9	2.4	76.2
15/8	44	7.6	10.6	24.2	57.6
21/8	40	7.3	12.2	9.8	70.7
27/8	64	14.6	16.7	37.5	31.2
4/9	42	6.7	8.9	24.4	60.0
12/9	48	11.8	8.8	29.4	50.0
18/9	46	14.3	11.4	25.7	48.6
25/9	34	5.3	5.3	21.0	68.4
2/10	44	5.0	15.0	27.5	52.5
10/10	40	0	14.8	18.5	66.7
15/10	32	14.3	9.5	19.1	57.1

Table 63 shows that 46% of the fruit had eggs laid on them. Of those 46%, each fruit had an average of 1.56 eggs laid on them.

Analysis of the data on the preferred oviposition site on the fruit shows that the tip of the fruit had significantly ($P < 0.05$) more eggs laid in that position compared to any other position on the fruit. It also shows that the side of the fruit has significantly more eggs laid there than on the stem of the fruit.

Figure 31 shows the numbers of eggs laid on each fruit. These data are based on 268 observations, and the number of eggs laid on a fruit varied from 1 to 13.

Figure 31. Percentage of the numbers of eggs laid on each fruit.



The data for Figure 31 showed that 60% of the fruit have a single egg laid on them. The percentage of fruit that have multiple numbers of eggs deposited on them decreased as the number of eggs per fruit increased.

Figure 32 shows the number of larvae found in each fruit.

Figure 32. Percentage of fruit with 1 or more larvae.

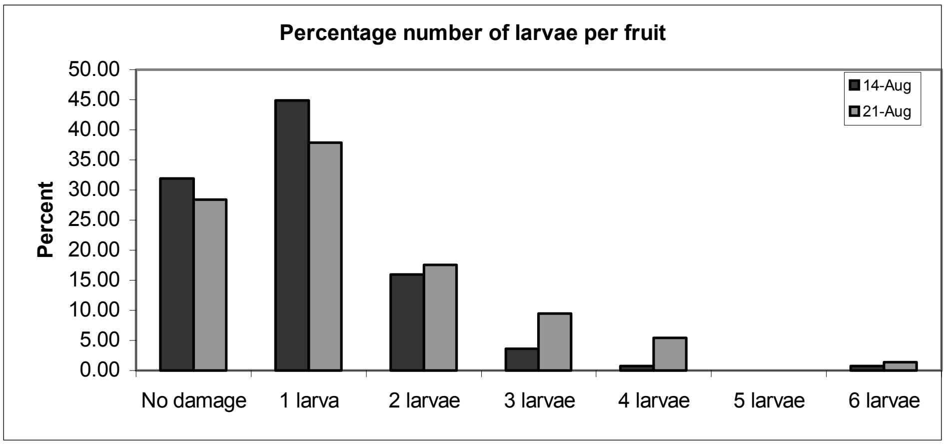


Figure 32 shows that the majority of damaged fruit only have 1 larva per fruit. No larval cannabism was observed.

Egg and larval growth studies
Section 2 (f)
Field collected eggs were held in the laboratory at approximately 25^0C to note the time from eggs being laid to emerging. Some of the eggs displayed different colour variations, some white and others with a red stripe down the sides. No differences were noted between the different egg colours in the time it took to emerge. On average, the time taken to emerging was 4 to 5 days. The difference could be due to age variations when the eggs were collected. It has been noted that the red stripe that develops on the fruit occurs within the first day.

Attempting to breed eggfruit caterpillar larvae through the different instars to adults failed. Very young larvae were set up in temperatures ranging from 14^0C to 39^0C but none survived past day 2.

Section 3 - Commercial crop studies
Section 3 (a)
Table 64 gives the number of eggs and larvae found from sampling 30 fruit. The position on the fruit where these eggs were found is given.

Table 64. Number and position on fruit for eggfruit caterpillar, Heliothis and leaf miner eggs and larvae.

Date	POSITION															
	1				2				3				4			
	Eggfruit cat.	Heliothis		Leaf miner	Eggfruit cat.	Heliothis		Leaf miner	Eggfruit cat.	Heliothis		Leaf miner	Eggfruit cat.	Heliothis		Leaf miner
		Egg	Lar.			Egg	Lar.			Egg	Lar.			Egg	Lar.	
13/5		4				18				20				10		
20/5		2				7				6				6	2	2
27/5						1				1			1	3	1	
5/6						1				1				1	1	
12/6		1				1								6		
17/6														1	2	
24/6		1													1	

Table 64 shows that most of the eggs detected were Heliothis eggs with 2 leaf miner eggs detected on the 25th May and 1 eggfruit caterpillar egg on the 27th May. Most Heliothis occurs on the fruit, with only 9% of the eggs found on the fruit stem. As this sampling was mainly for eggfruit caterpillar, it was known that most of their eggs are laid around the fruit whereas Heliothis eggs have been collected from all sections on eggplant crops.

The low number of eggfruit caterpillar eggs coincided with an average of 0.6 moths per day being caught at the pheromone traps between the 6th and 30th May.

Section 3 (b)

Table 65 gives the number of insect pests collected off 100 leaves. The SLWF counts are based on the number of honeydew drops counted off 30 leaves.

Table 65. Average number of insect pests off 100 leaves or off 30 leaves for SLWF.

Date	Heliothis		Eggfruit caterpillar	SLWF	Leaf miner	Thrips	Aphids	Jassid
	Egg	Larvae	Egg	Av. per leaf	Egg			
11/4	1	0	0	1.37	0	1	56	5
17/4	4	0	0	1.09	1	2	17	1
24/4	5	0	0	2.39	0	0	1	
30/4	23	0	2	2.7	0	0	6	
13/5	52	0	0	106.3	0	0		
20/5	21	2	0	73.3	0	0		
27/5	5	1	1	72.2	0	0		
4/6	3	1	0	142.8	0	0		
11/6	8	0	0	273.3	0	0		
17/6	1	2	0	281.0	0	0		
26/6	1	1	0	707.6	0	0		

Table 65 shows that the SLWF populations kept increasing from the first sampling date to the last. These are very high numbers. The decrease in aphid numbers was probably due to the increasing populations of SLWF that compete for the same areas on the leaf to feed.

Table 66 gives the number of beneficial insects collected off the same 100 leaves as used to count the pest numbers.

Table 66. Number of beneficial insects recorded off 100 leaves.

Date	**Ladybird**			**Lacewing**			**Spiders**	**Big eyed bug**	**Broken back bug**
	Egg	**Larvae**	**Adult**	**Egg**	**larvae**	**Adult**			
11/4	1			1			11	3	
17/4							4	1	4
24/4				5			6	1	
30/4				2			1	1	2
13/5			1	2			7		
20/5				3			4		
27/5				1					

Table 66 shows that there were few beneficial insects in the crop. No lacewing larvae developed from these eggs counted at sampling. Spiders were present in the crop.

Section 3 (c)

Table 67 gives the number of insects found on a plant. Ten plants were cut and brought back to the laboratory. These plants sweated from being sealed in plastic bags, as there was no other simple method of storing them until examined. Consequently only 1 plant was examined. This sampling method is not efficient and the results could not be compared to sub-samples of the leaves.

Table 67. Number of insects collected off one eggplant bush.

PESTS	**Insect stage**	**Number**	**BENEFICIAL INSECTS**	**Insect stage**	**Number**
Heliothis	Egg	16	**Ladybird**	Egg	1
	Larvae	4		Larvae	3
Leaf miner		5		Adult	2
Thrips		14	**Lacewing**	Egg	13
Aphids		189		Larvae	
Jassid		1		Adult	5
Loopers		1	**Spiders**		6
Mites		47	**Predatory mites**		3
Cricket		3			
Red shouldered leaf beetle		1			

Table 67 shows that aphids were the dominant species of the insects. A number of beneficial insects were recorded and from observations in other crops these numbers are typical of most crops. Mites were present but the plant did not appear to be showing any effects from their numbers. Sub-sampling of leaves does not detect mites unless using a magnifying lens. Heliothis eggs were found throughout the plant but the larvae are mainly detected in the fruit.

Table 68 gives the results from collections of Heliothis eggs off eggplants to record parasitism levels.

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 33. Total number per month at Gumlu site 1.

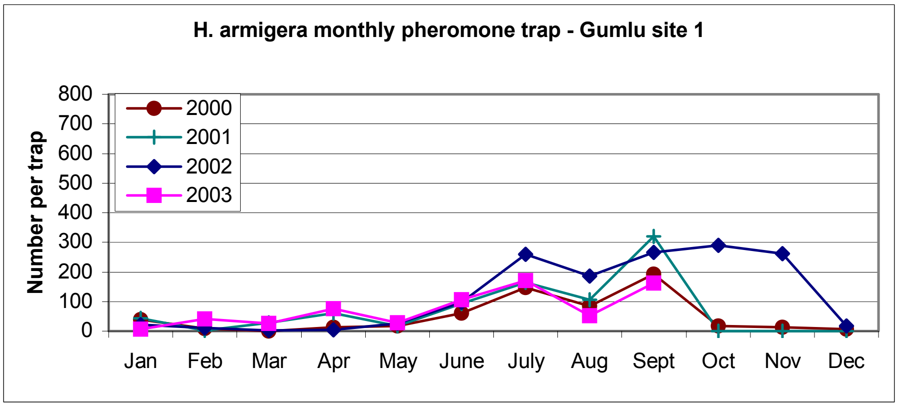
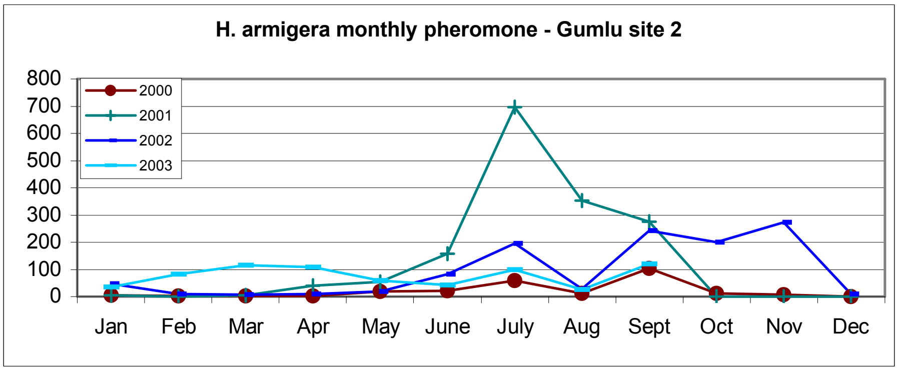
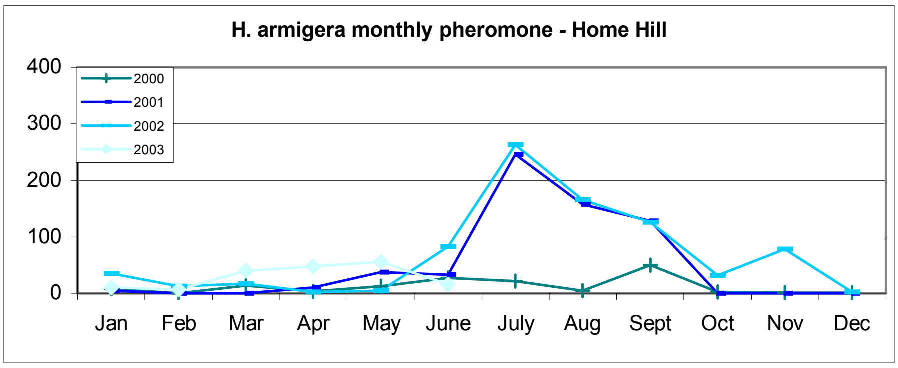


Figure 34. Total number per month at Gumlu site 2.



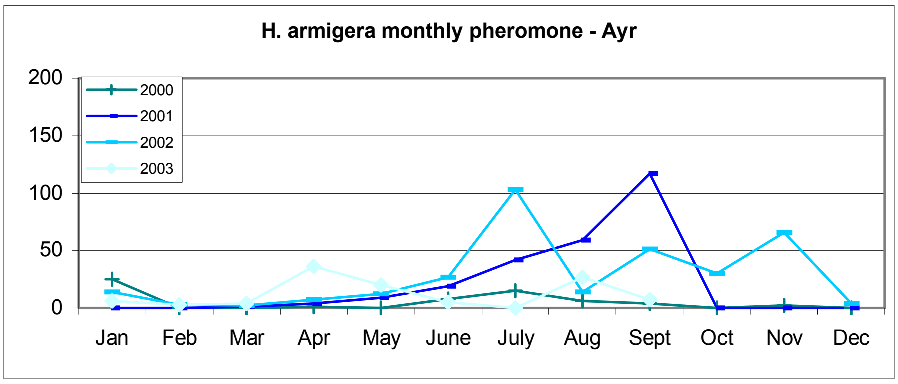
Comparing the two Gumlu sites, it shows the Gumlu site 1 had approximately twice as many moths caught over the years except for 2001.

Figure 35. Total number per month at Home Hill.



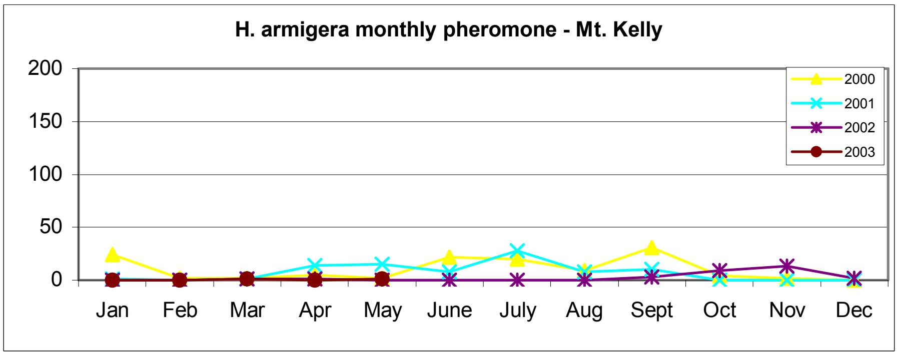
Similar numbers were collected in the 2001 and 2002 years but the numbers in the year 2000 are low. The numbers are lower than the Gumlu sites. Note the different scale range.

Figure 36. Total number per month at Ayr.



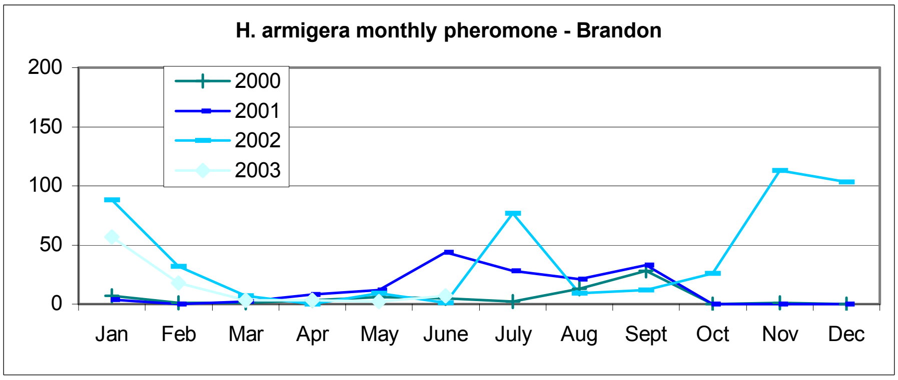
Numbers collected at this site are high in the years 2001 and 2002 compared to the year 2000. The numbers collected are lower than Home Hill. Note the different scale range.

Figure 37. Total number per month at Mt. Kelly.



This site had very low numbers for most years compared to the other sites.

Figure 38. Total number per month at Brandon.



This site also had low numbers.

Figures 39 to 44 show the trapping data for *H. punctigera* from six sites. The data covers the years 2000 to 2003.

Figure 39. Total number per month at Gumlu site 1.

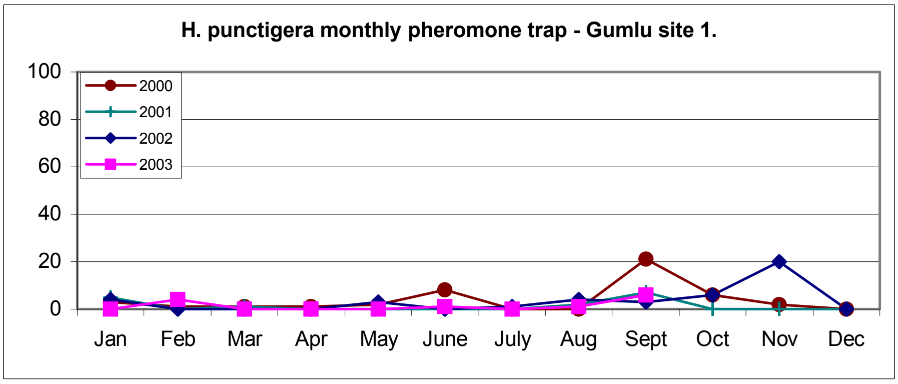
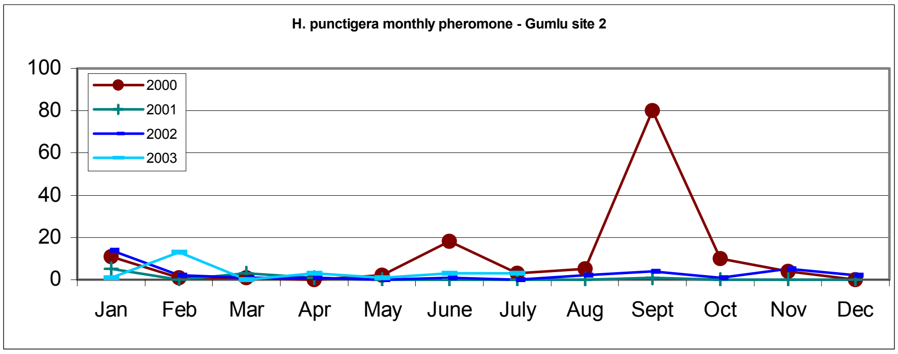
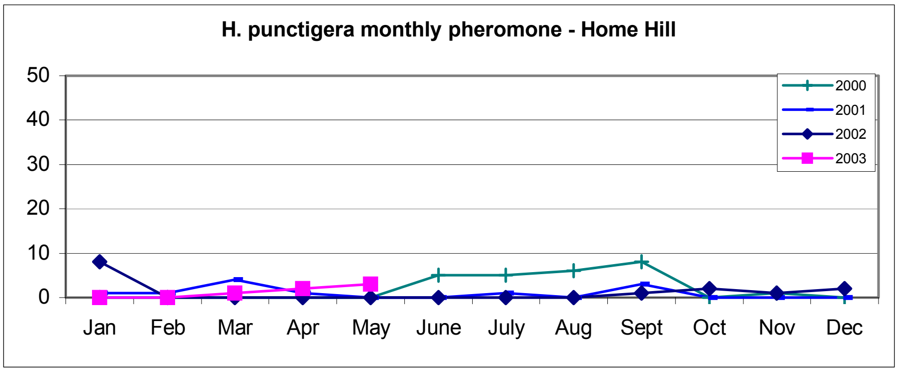


Figure 40. Total number per month at Gumlu site 2.



The Gumlu site 2 had higher numbers than Gumlu site 1. The main period of activity is between July and October.

Figure 41. Total number per month at Home Hill.



The populations recorded at this site are low compared to the Gumlu sites. Note the different scale range.

Figure 42. Total number per month at Ayr.

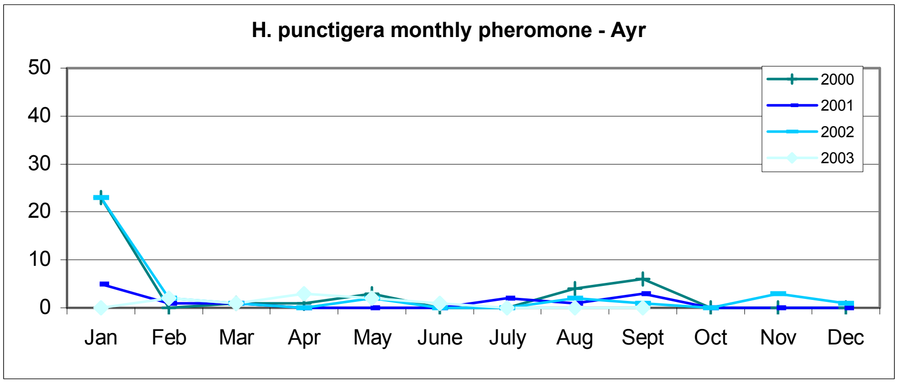


Figure 43. Total number per month at Mt. Kelly.

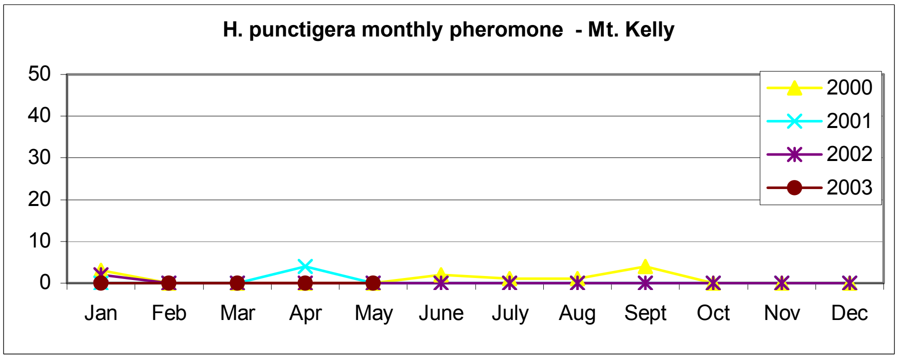
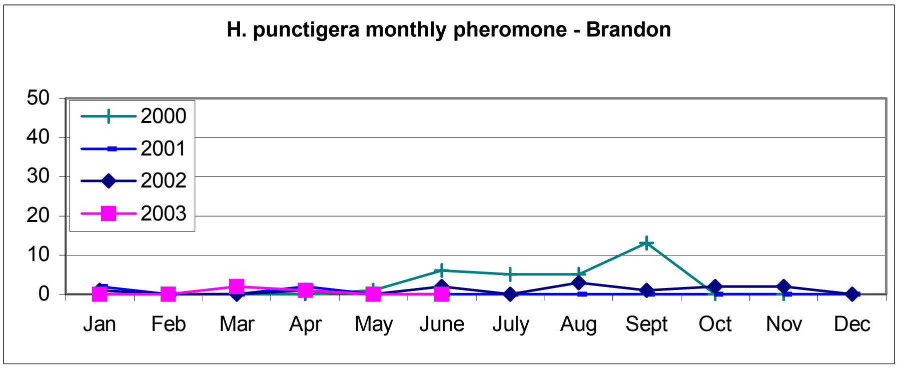


Figure 44. Total number per month at Brandon.



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.

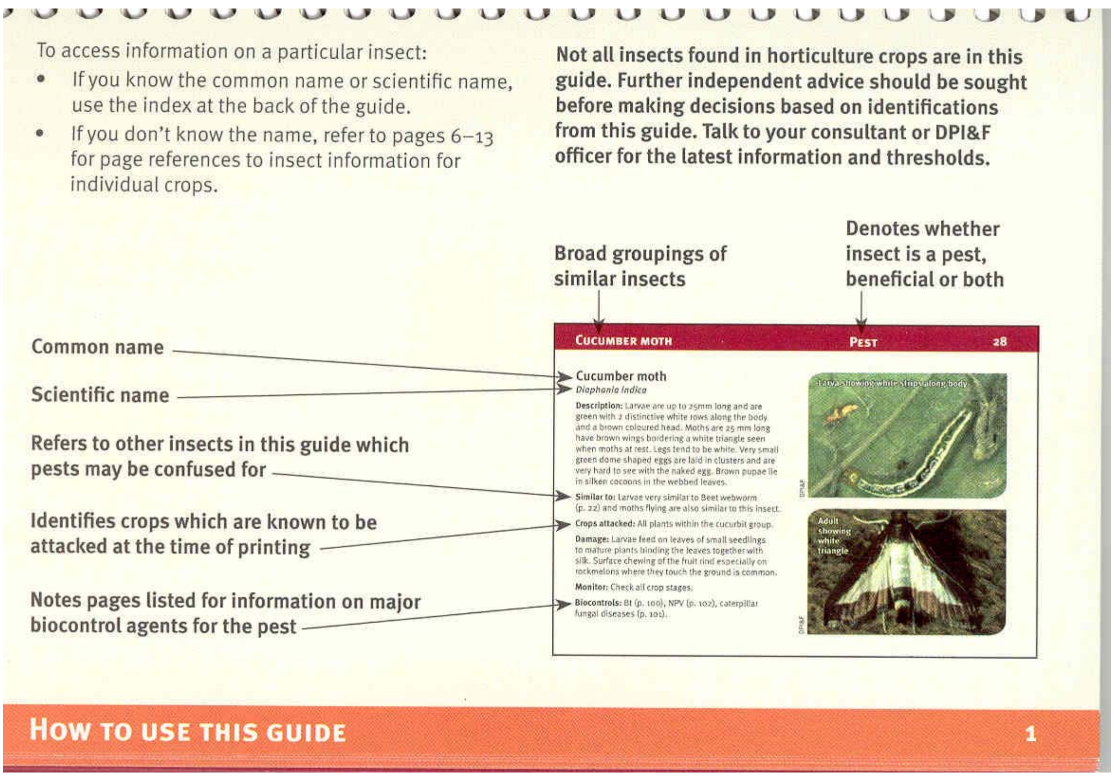
TECHNOLOGY TRANSFER

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:

How to use this guide	Page 1
Purpose of this guide	Page 2
Glossary and insect diagram	Page 3
Acknowledgements	Page 4
Further reading	Page 5
Crop pest listings	
Beans	Page 6
Capsicum	Page 7
Cucurbits	Page 8
Eggplant	Page 10
Sweet corn	Page 11
Tomato	Page 12
Insects	Pages 14 - 61
Beneficial groups	Pages 62 - 102
Index	Pages 103 – 106

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.

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Department of Primary Industries
Queensland Horticulture Institute
PO Box 591
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Ayr, Qld
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22/01/01

RE: Implementing Integrated Pest Management Systems (IPM) in Capsicum and Eggfruit Crops.

To whom it may concern,

Queensland Department of Primary Industries (QDPI) staff in Ayr are currently undertaking a project aimed at implementing IPM systems into capsicum and eggfruit crops. To initiate the process we need to obtain information on the current management practices of growers for the control of insects in eggfruit and capsicum crops. We are asking that you take five minutes to fill in the following questionnaire and to return it in the enclosed envelope by the 29th February, 2001.

We appreciate your cooperation in undertaking this survey. We assure you that it will benefit the industry in the future. Thank you!

Yours sincerely,

J. Brown
(Principal Experimentalist)

K.Gooding
(Development Extension Officer)

Grower survey

Please return in the enclosed envelope by the 28/01/01

Implementing Integrated Pest Management (IPM) Systems in Capsicum and Eggfruit Crops.

NB: If you are not currently growing capsicum or eggfruit crops, we would still appreciate your responses where applicable.

Part 1: Farm details

1) Name (optional):
……………………………………………………………………………..

2) District:
………………………………………………………………………………………

3) Crops (list all crops grown):
…………………………………………………………………

…………………………………………………………………………………………
………...

4) If you grow both capsicum and eggfruit, which crop is more important to your farming situation? (please tick).

- ❑ Capsicum. Is this your main crop? Yes / No
- ❑ Eggfruit. Is this your main crop? Yes / No

5) Do you see an advantage in using an IPM system in your farming situation? (please tick)

- ❑ Yes
- ❑ No

If yes, for what reason? (please number in order of priority, with 1 being the highest priority and 5 being the lowest priority)

- ❑ Environmental reasons
- ❑ Market advantage
- ❑ Human health
- ❑ Cost input saving
- ❑ Other

………………………………………………………………………………………

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Part 2: Insect Identification

1) Please list in order of most problematic to least problematic, the major and minor insect pests in your capsicum and/or eggfruit operation. For help in answering this question please observe Appendix A (at end of survey). Feel free to use the corresponding numbers found in the appendix. (ie; Thrips are number 36, so just enter 36 below, instead of writing 'thrips'). The list is not exhaustive, so if an insect is not listed please enter regardless.

Major pests		**Minor pests**	
Capsicum	Eggfruit	Capsicum	Eggfruit

2) Do you have problems in controlling any of the above pests? (please tick)

- ❑ Yes
- ❑ No

If yes, which ones? (please list)

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……………………………………………...

……………………………………….….
………………………….……………………..

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3) Do you know how to recognise beneficial insects in your crops? (please tick)

- ❑ Yes
- ❑ No
- ❑ Some

If yes, please list those beneficial insects found in your cropping situation.

1) ……..…..……………………………… 5) ……………………………………….

2) ………..……………………………….. 6) ……………………………………….

3) ……...………………………………… 7) ……………………………………….

4) ……..………………………………….. 8) ………………………………………..

4) Of these beneficials can you distinguish between predators and parasites? (please tick)

❑ Yes
❑ No

If yes, please indicate in the list above (question 2), by writing 'pred' next to those that are predators and 'para' next to those that are parasites.

5) If you do have beneficial insects in your farming situation, were they……? (please tick).

❑ Introduced as a part of a management system implemented by yourself.
❑ Introduced as a part of a management system implemented by a consultant
❑ Always there, occurring naturally.
❑ Other.
Please specify
………………………………………………….………………………..

….…………………………………………………………………………………………

6) Do you have any books/photographs that show and help to distinguish the insects relevant
to your farming? (please tick)

❑ Yes
❑ No

7) If it were run, would you be interested in attending an Insect Identification workshop? (please tick)

❑ Yes
❑ No

Part 3) Management decisions.

1) On what basis do you make your insect management decisions? (please tick)

❑ Routine spray schedule.
❑ Monitoring and observation of insect populations by yourself.

- ❑ Monitoring and observation of insect populations by a crop consultant.
- ❑ As a part of a spray program for disease control
- ❑ Other.
  Please specify
  …………………………………………………………………………...

  …………………………………………………………………………………
  ………...

……………………………………………………………………………………..

2) If you do base your decisions on monitoring, at what frequency do you or your consultant monitor your crops? (please tick).

- ❑ Daily
- ❑ Twice a week
- ❑ Once a week
- ❑ Once a fortnight
- ❑ Once a month
- ❑ Other
  Please specify
  ……………………………………………………………………………

  …………………………………………………………………………………
  ………

……………………………………………………………………………………

3) If you do use a monitoring/scouting system would you be prepared at some stage to discuss the method and its appropriateness with DPI staff? (This will be aimed at providing benefit to both parties).

- ❑ Yes
- ❑ No

Part 4) Future possibilities

1) If a scouting/monitoring system was introduced to the area would you be prepared to use
it? (please tick)

- ❑ Yes
- ❑ No

If yes, and you were given the chance to learn the correct monitoring procedures, would you undertake the monitoring yourself, use a crop consultant or both? (please indicate your preference at this stage)

- ❑ Self
- ❑ Crop Consultant
- ❑ Both

2) As a part of this project would you be interested in having trials conducted on your farm? (please tick)

- ❑ Yes
- ❑ No

3) Would you be interested in attending field days and demonstration days, either on farm or at a Research Station if they were run? (please tick)

- ❑ Yes
- ❑ No

4) Are there any other comments you would like to make, either regarding this survey or
about the work being undertaken?

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………...

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End of Survey.
Thank you for your cooperation. This survey will aid in further improving the vegetable industry

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Appendix A

LIST OF INSECTS

This list contains a range of commonly used names. Not all insects referred to in this list are commonly found in these crops. Select the number of the insect that you are referring to or write its name in the spaces provided.

1. Ants
2. Aphids
3. Aphid Parasites
4. Armyworms
5. Assassin bugs
6. Atherigona

7. Bean fly
8. Bees
9. Broad Mite
10. Bugs

11. Cluster caterpillar
12. Crickets
13. Cutworms

14. Egg Parasites
15. Eggfruit caterpillar

16. False wireworm
17. Flea Beetles
18. Fruit Flies

19. Green Peach Aphid
20. Green Stink Bug
21. Green Vegetable Bug

22. Heliothis
23. Hoover Flies
24. Lacewings
25. Ladybeetles
26. Leaf eating Ladybeetles
27. Leaf hoppers
28. Leaf Miner

29. Mites
30. Mole cricket

31. Potato Moth

32. Queensland Fruit Fly

33. Spider Mites
34. Spiders
35. Syrphid flies

36. Thrips
37. Trichogramma

38. Vegetable Jassid

39. Wasps
40. Wireworms

41. Yellow peach moth

MAIN STRUCTURE OF CAPSICUM PLANT

FIGURE 1.

A branch structure forms at each leaf junction.
It also appears that there are 9 -10 leaves before branching into 2 or 3 branches at the tip, which mostly has a single flower at the base of this branching. Sometimes 2 flowers.

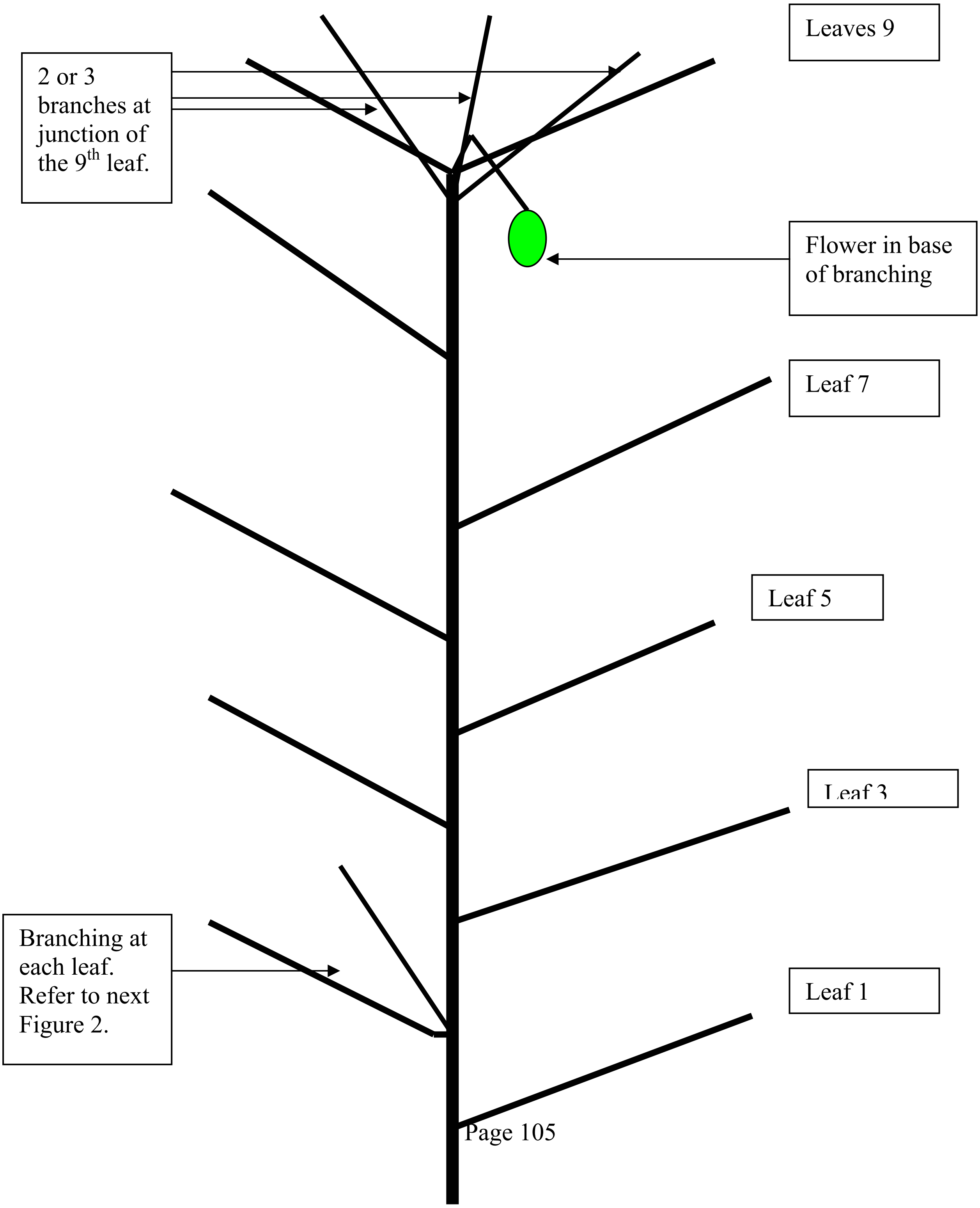

FIGURE 2.

STRUCTURE OF BRANCHING FROM LEAF JUNCTIONS.

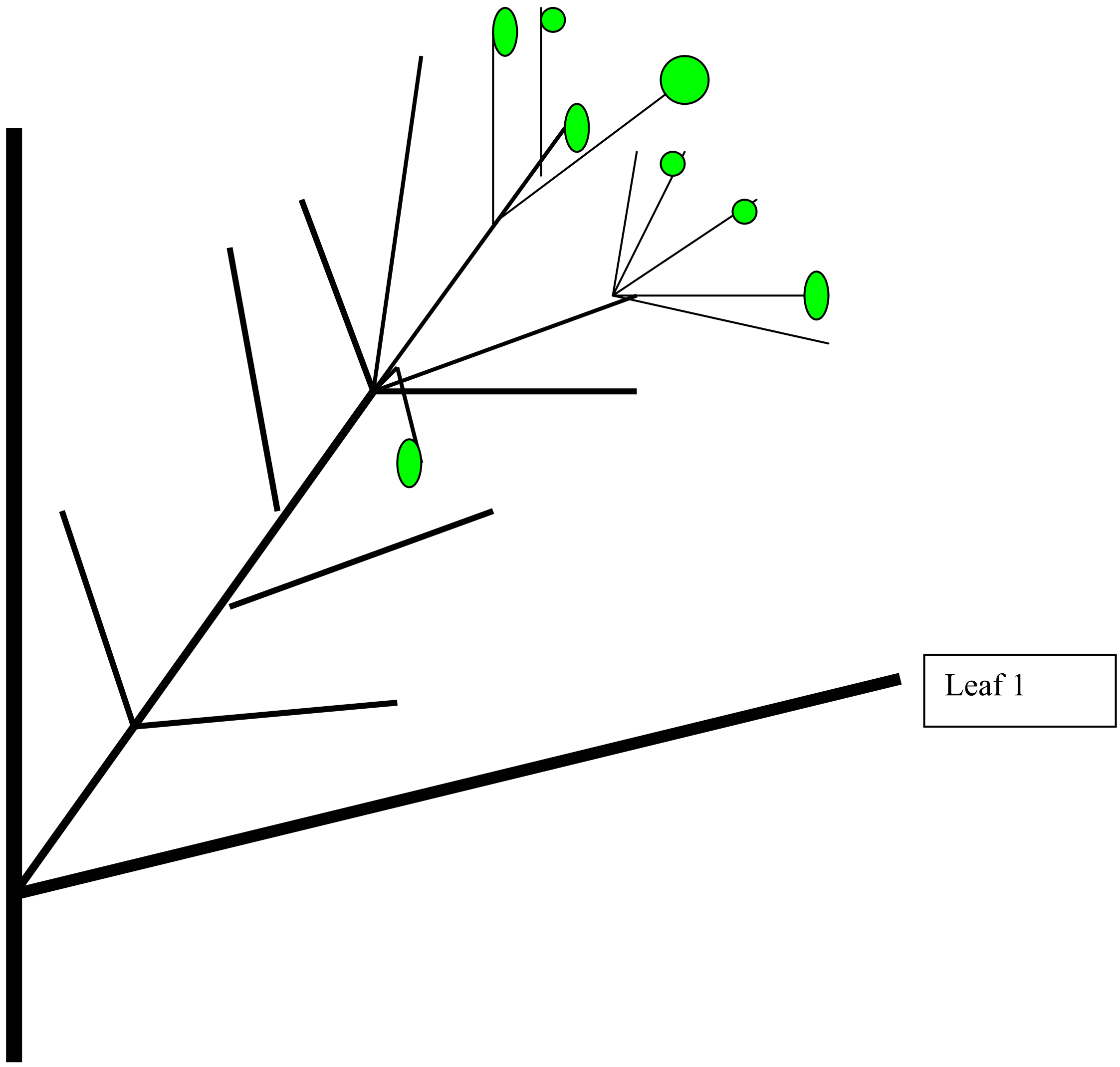

FIGURE 3.

STRUCTURE AT BRANCHING AFTER 9th LEAF.