Part 1 - Summary Details

CRDC Project Number: **DAN 160C**

Project Title: Impact and role of novel insecticides in integrated pest management

Project Commencement Date: 01 – 07 - 02 **Project Completion Date:** 30 – 06 - 05

Research Program: On-Farm

Part 2 – Contact Details

Administrator: Mr. Graham Denney
Organisation: New South Wales Department of Primary Industries
Postal Address: Locked bag 21, Orange NSW 2800
Ph: 02 6391 3219 **Fax:** 02 6391 3327 **E-mail:** graham.denney@agric.nsw.gov.au

Principal Researcher: Mr. Viliami Heimoana
Organisation: New South Wales Department of Primary Industries
Postal Address: Locked bag 1000, Narrabri NSW 2390
Ph: 02 6799 1516 **Fax:** 02 6799 1503 **E-mail:** viliamih@mv.pi.csiro.au

Supervisor: Dr. Robert Mensah
Organisation: New South Wales Department of Primary Industries
Postal Address: Locked bag 1000, Narrabri NSW 2390
Ph: 02 67991547 **Fax:** 02 6799 1503 **E-mail:** robert.mensah@agric.nsw.gov.au

Signature of Research Provider Representative: ______________________________

Part 3.3 – Final Reports (due 3 months after completion of project)

Background

The introduction of Bt-gene cotton varieties has reduced insecticide use to a large extent, particularly on Bt cotton crops, however, growers still need protection against *Helicoverpa* late in the season on Bt crops and throughout the season on conventional cotton crops. This is because despite the increase in GM cotton plantings, significant areas of conventional cotton are still being grown, some of which are used as refuge crops for beneficial insects, and the need of insecticides in these crops for *Helicoverpa* management is still important.

IPM in GM crops includes reduced early season spraying and the use of 'soft options' spray schedules. This enables secondary pests to become more important as they are not co-incidentally controlled by broad spectrum chemistry. Aphids are a secondary pest of Australian cotton with the potential to become a major pest. Aphid resistance and cross resistance to some insecticides has become a problem for growers. Aphids are also possible vectors of bunchy top disease, which has increased the used of insecticides against aphids. Preliminary results from previous year's trials have shown that some of the new insecticides are not as soft to beneficial as they are claimed to be. It was also observed that some of these new insecticides might cause possible 'flaring' of secondary pests such as aphids and mites by reducing the number of beneficials in a crop. Therefore, trials are conducted to validate the results of the label rates of insecticides claimed by the product developers (chemical companies) and also develop appropriate insecticide use strategies for the Bt cotton crops.

In this project, new insecticides (both newly registered and yet to be registered) were tested for their efficacy in controlling *Helicoverpa* spp and *Aphis* spp. This project also generated an independent dataset on efficacy and impact of specific chemicals on other pests and non-target species (beneficials). The use of the unique eight-line spray rig (funded by CRDC and built to specification) has enabled the precise and efficient evaluation of insecticides in the field situation. The project also collaborates with Dr. Lewis Wilson, Dr. Robert Mensah, Dr. Grant Herron and other IPM and IRM researchers on insecticide efficacy.

Objectives

(i) Evaluate efficacy of new insecticides for controlling of Helicoverpa species

The insecticides tested for *Helicoverpa* control included: 2002/03 - Amorphous silica - Abrade® 50% a.i. (Grow Choice Pty. Ltd), Azadirachtin - Azamax® 1% a.i. (OCP Pty. Ltd.), Semicarbazone – BASF320 200g a.i. (BASF), NPV - Gemstar® (Bayer Cropscience), Methoxyfenocide - Prodigy® 240g/L a.i. (Dow Agrosciences), Novaluron - Rimon® 100g/L a.i. (Nurfarm), Phenyl ether derivative - S1812 50% a.i. (Sumitomo) and Indoxacarb - Steward® 200 g/L (Dupont). In 2003/04 the same set of insecticides was used with only one change where NPV was dropped and Chlofenapyr - Intrepid® 360 g/L a.i. (Nurfarm) included. In 2004/05 Amorphous silica, Azadirachtin, Semicarbazone an Indoxacarb were still in the trials plus a new formulations such as DPXKN128 EC (Dupont), Endosulfan SC 350 g/L (Bayer Cropscience) and Flubendiamide – NNI-0001 SC 480 g/L a.i. (Bayer Cropscience).

Helicoverpa pressure during the 2002/03 was quite low compared to that in the 2003/04 and 2004/05 seasons, however, there were still sufficient eggs and larvae to show efficacy differences between various chemicals when compared to the untreated control.

Some of the new products tested Indoxacarb, Phenyl ether derivative, Flubendiamide, Semicarbazone proved to be very effective in controlling *Helicoverpa* species at various stages of the *Helicoverpa* life cycle and during the season. Novaluron, Methoxyfenocide and Amorphous silica were the least effective when compared to the untreated control.

(ii) Evaluate the efficacy of new insecticides for controlling aphids in transgenic cotton.
Insecticide tested for *Aphis* control were the same for 2002/03, 2003/04 and 2004/05. They included, Acetamiprid – Intruder® 225g/L a.i. (Dupont), Carbosulfan – 'new Marshal' 250 g/L a.i. (Crop Care), Clothianidine – TI-435 16% a.i. (Sumitomo), Imidacloprid – Confidor® 200g/L a.i. (Bayer Cropscience), Pirimicarb – Pirimor® 500g/L a.i. (Syngenta), Pymetrozine – Chess® 500g/L a.i. (Syngenta), Pyriproxifen – Sumilav® 20g/L a.i. (Sumitomo) and Thiamethoxam – Actara® 250g/L a.i. (Syngenta).

New insecticides formulation such as Acetamiprid, Carbosulfan and Thiamethoxam proved to be very effective in controlling aphids while Pirimicarb was the least effective. In some cases Pirimicarb was worse than the untreated control.

(iii) Assess the impact of new chemistries on other pests and beneficial insects

The following chemicals were also evaluated for their impact on beneficial insects and arachnids:

Amorphous silica - Abrade® 50% a.i. (Grow Choice Pty. Ltd), Azadirachtin - Azamax® 1% a.i. (OCP Pty. Ltd.), Semicarbazone – BASF320 200g a.i. (BASF), NPV - Gemstar® (Bayer Cropscience), Methoxyfenocide - Prodigy® 240g/L a.i. (Dow Agrosciences), Novaluron - Rimon® 100g/L a.i. (Nurfarm), Phenyl ether derivative - S1812 50% a.i. (Sumitomo), Indoxacarb - Steward® 200 g/L (Dupont), Chlofenapyr - Intrepid® 360 g/L a.i. (Nurfarm), DPXKN128 EC (Dupont), Endosulfan SC 350 g/L (Bayer Cropscience), Flubendiamide – NNI-0001 SC 480 g/L a.i. (Bayer Cropscience), Acetamiprid – Intruder® 225g/L a.i. (Dupont), Carbosulfan – 'new Marshal' 250 g/L a.i. (Crop Care), Clothianidine – TI-435 16% a.i. (Sumitomo), Imidacloprid – Confidor® 200g/L a.i. (Bayer Cropscience), Pirimicarb – Pirimor® 500g/L a.i. (Syngenta), Pymetrozine – Chess® 500g/L a.i. (Syngenta), Pyriproxifen – Sumilav® 20g/L a.i. (Sumitomo) and Thiamethoxam – Actara® 250g/L a.i. (Syngenta).

Significant effects: Abrade and Rimon reduced beneficial Coleoptera, Stewart reduced 2-spotted ladybird beetles and ants while BASF320 and Intrepid reduced Hymenoptera (wasps). Acetamiprid, Carbosulfan and Thiamethoxam all consistently reduced beneficials. Imidacloprid and Clothianidine were softer on beneficial insects.

Methodology

Unless otherwise stated all insecticide trials were carried out on irrigated Bt and conventional cotton crops at the Australian Cotton Research Institute in Narrabri. During the three years of this project research has been carried out on both synthetic and biological insecticides. The cotton varieties used for the studies were: Sicot 189RR (conventional) and Sicot 289RR and Sicot 289BR (transgenic). The planting rate was 15 plants/m. Experimental designs used were randomised complete block design (RCBD) and split block design. Trials were replicated 4 times in plots and insecticide treatments and control allocated to plots. New chemistry insecticides tested against *Helicoverpa* control includes: (2002/03) - Amorphous silica - Abrade® 50% a.i. (Grow Choice Pty. Ltd), Azadirachtin - Azamax® 1% a.i. (OCP Pty. Ltd.), Semicarbazone – BASF320 200g a.i. (BASF), NPV - Gemstar® (Bayer Cropscience), Methoxyfenocide - Prodigy® 240g/L a.i. (Dow Agrosciences), Novaluron - Rimon® 100g/L a.i. (Nurfarm), Phenyl ether derivative - S1812 50% a.i. (Sumitomo) and

Indoxacarb - Steward® 200 g/L (Dupont). (2003/04) - Amorphous silica - Abrade® 50% a.i. (Grow Choice Pty. Ltd), Azadirachtin - Azamax® 1% a.i. (OCP Pty. Ltd.), Semicarbazone – BASF320 200g a.i. (BASF), Methoxyfenocide - Prodigy® 240g/L a.i. (Dow Agrosciences), Novaluron - Rimon® 100g/L a.i. (Nurfarm), Phenyl ether derivative - S1812 and Chlofenapyr - Intrepid® 360 g/L a.i. (Nurfarm). (2004/05) - Amorphous silica, Azadirachtin, Semicarbazone and Indoxacarb were still in the trials. Intrepid, prodigy and S1812 were replaced with Endosufan SC (suspension concentrate), Endosulfan EC (emulsifiable concentrate), Flubendiamide (NNI-0001) and Indoxacarb (Steward® & DPXKN128). DPXKN128 EC is a different formulation of indoxacarb which is supposedly less toxic to beneficial insects than Steward SC. The trial was carried out in Bollogard II and Conventional varieties.

New chemistry insecticides tested against *Aphis* spp. control were the same for 2002/03, 2003/04 and 2004/05. It includes, Acetamiprid – Intruder® 225g/L a.i. (Dupont), Carbosulfan – 'new Marshal' 250 g/L a.i. (Crop Care), Clothianidine – TI-435 16% a.i. (Sumitomo), Imidacloprid – Confidor® 200g/L a.i. (Bayer Cropscience), Pirimicarb – Pirimor® 500g/L a.i. (Syngenta), Pymetrozine – Chess® 500g/L a.i. (Syngenta), Pyriproxifen – Sumilav® 20g/L a.i. (Sumitomo) and Thiamethoxam – Actara® 250g/L a.i. (Syngenta).

The insecticide tested in all the three year studies are given in Table 1.

Table 1: Insecticides used in project trials 2002-2005

Insecticide	Trade name	Chemical group	Form	Prod.Rate/ha
For *Helicoverpa*				
Amorphous silica	Abrade	Irritant	SC	5.0 L
Azadirachtin	AzaMax	Botanical	EC	0.1 L
Semicarbazone	BASF320	Propylene glycol	SC	1.0 L
Indoxacarb	Steward	Indoxadiazine	SC	0.65 L
Indoxacarb (new formula)	DPXKN 128	Indoxadiazine	SC	0.65 L
Chlorfenapyr	Intrepid	Pyrole	SC	1.1 L
Methoxyfenocide	Prodigy	IGR	EC	1.66 L
Novaluron	Rimon		EC	1.0 L
S1812		Phenyl ether derv.	EC	0.2 L
NPV	Gemstar	BT		0.5 L
NNI-0001		Flubendiamide	SC	0.2 L
For *Aphis*				
Carbosulfan	Marshall	Carbamate	EC	1.75 L
Endosulfan	Endo SC (new)	Organochlorine	SC	2.1 L
TI-435		Chlothianidine	WP	0.313 Kg
Imidacloprid	Confidor	Chloronicotinyl	SC	0.300 L
Pirimicarb	Pirimor	Carbamate	WG	0.75 Kg
Pymetrozine	Fulfil		WG	0.400 Kg
Pyriproxifen	Admiral		EC	0.1 L
Thiamethoxam	Actara	Chloronicotinyl	WG	0.4 Kg

The insecticides were applied using a specially constructed spray rig with hollow cone nozzles (TX4 or TX6), at 3 bar pressure and 5km/hr speed to deliver commercial application volumes of 100 and 150 L/ha. The sprayrig enabled the simultaneous application of 8 chemicals per run. Sprays are applied when the target insects reach the cotton industry recommended threshold (Helicoverpa = 0.5/m; Aphis 50% plants infested (early) and 10% of plants infested mid/late season).

Trial assessments:
Helicoverpa spp., the number of eggs and larvae were counted 24 hours before and 2, 5, 7 and 10 days after treatment application. The total number of *Helicoverpa* eggs and larvae were visually assessed (bug checked) on a metre row of cotton in each treated plot. Vacuum sampling (Dvac, Homelite) were used to sample other insects in each treated plot. In Dvac sampling a 15 m row was sampled in each plot. The tube of the vacuum sampler is passing in a figure 8 movements along the top of the plants in 15 m of row. Dvac samples were processed in the laboratory and all insects were identified and counted under a stereo microscope. All data (visual and Dvac) were expressed as numbers per metre

In the aphid trials, all plots were artificially infested with aphids in mid-December. Spraying and assessment occurred at the same time as in Helicoverpa trial. Visual estimates or scoring system on 20 leaves per plot was used to assess aphid numbers. The scoring system used were **0** = 0, **1** = 1-10, **2** = 11-20, **3** = 21-50, **4** = 51-100, **5** = > 100. In addition 20 leaves (same 20 leaves which was scored) per plot were collected into plastic bags and washed in the laboratory. The samples were then washed onto filter paper discs, transferred to petri dishes and the numbers of aphids per treated plot were recorded. The score system provided instant information that allowed for management decisions at that point in time (eg. parasitism, mite flare ups and predation). All data were analysed using Genstat for Windows, 7th Edition.

Results
2002-03 Helicoverpa trial
The results showed that there was significant difference between conventional and Ingard cotton varieties despite low *Helicoverpa* numbers in all treated plots as a result of the drought. There were no varietal effects on egg numbers. The numbers of very small larvae recorded in the Ingard cotton crops were 32.8 % lower than in the Conventional cotton crops (Appendix 1, Table 1). No larger sized larvae survived on Ingard cotton crops compared to the conventional crops indicating good efficacy of the Bt toxin against Helicoverpa spp. Data from Dvac sample showed that Abrade and Rimon had 16 and 18% respectively higher jassid numbers than the control plots (Appendix 1, Table 3). In addition Abrade had 15% more total Hemiptera pests than the control treatment. Furthermore Abrade significantly reduced the number of red and blue beetles and total Coleoptera beneficial insects by 34.1% and 27.7%. Gemstar reduced the numbers of red and blue beetles by 42.5% and Coleopteran predators by 39% relative to the control. Rimon reduced red and blue beetles by 30.2% and Coleopteran predators by 28.6% relative to the control (Appendix 1, Table 4). The study also showed that numbers of ADB and other hemipteran pests on the Gemstar treated plots were significantly lower than the control plots. Apart from red and blue beetles and the coleopteran predators none of the other predatory insects were significantly affected by the chemicals tested. In terms of Green mirids, BASF320, Rimon and Steward had 49.2, 46.0 and 46.1 respectively less green mirid than the control and were the most effective chemical in the control of sucking pests. *Helicoverpa* numbers from the visual counts were extremely low and did not show up any differences in efficacy between the treatments. However, the number of *Helicoverpa* spp. larval recorded from the Dvac samples showed that the Gemstar treated plots had significantly lower *Helicoverpa* spp. larvae (54%) and S1812 chemical had 62.7% lower larval than the control plots.

Aphid Trial

All chemicals tested significantly reduced the number of aphids per leaf compared to the untreated control (Table 2). Acetamiprid, carbosulfan and thiamethoxam were the most effective control options, however, they also had the greatest impact on beneficials. Beneficials of aphids include parasitic wasps, pirate bugs, chamaemyiid flies and syrphid, lacewing and ladybird beetle larvae as well as adult ladybird beetles.

Table 2: Effects of insecticides on the abundance of aphids and beneficials on cotton, ACRI 2002/03

Treatment	Aphids/leaf		Adults/leaf		Nymphs/leaf		Alatae/leaf		Beneficials/leaf	
	mean	%	mean	%	mean	%	mean	%	mean	%
Acetamiprid	195.64	-83.76*	2.54	-78.03*	188.22	-84.12*	4.88	-41.66*	3.46	-49.01*
Carbosulfan	219.28	-81.80*	2.82	-75.62*	212.01	-82.11*	4.45	-46.84*	3.98	-41.36*
Clothianidine	455.64	-62.19*	4.47	-61.37*	446.61	-62.32*	4.57	-45.37*	4.92	-27.48*
Imidacloprid	521.99	-56.69*	5.51	-52.39*	512.94	56.73*	3.55	-57.56*	4.52	-33.51*
Pirimicarb	1090.61	-9.51*	12.44	7.55	1071.10	-9.64*	7.08	-15.43*	5.19	-23.51*
Pymetrozine	556.99	-53.78*	6.54	-43.43*	545.27	-54.0*	5.18	-38.06*	4.10	-39.66*
Pyriproxifen	472.88	-60.76*	6.04	-47.82*	461.37	-61.08*	5.48	-34.55*	4.15	-38.81*
Thiamethoxam	273.53	-77.30*	2.72	-76.53*	265.97	-77.56*	4.85	-42.07*	3.67	-45.89*
Control	1205.30	0	11.57	0	1185.37	0	8.37	0	6.79	0
df	348		348		348		348		348	
LSD	81.17		1.208		79.91		1.189		1.282	

1. Values are means of data from washes
2. Values are percentage change compared to the control treatment
3. Asterisks in each column indicate treatments significantly different from the control at P=0.05.

Table 3: Efficacy rating for insecticides tested on aphids and beneficial insects in cotton, ACRI 2002/03

Chemical Treatment Rating	Total Aphids/leaf	Total Beneficials/leaf
Most efficacy	Acetamiprid (least survivors)	Control (most survivors)
↓	Carbosulfan	Pirimicarb
	Thiamethoxam	Clothianidine
	Clothianidine	Imidacloprid
	Pyriproxifen	Pyriproxifen
	Imidacloprid	Pymetrozine
	Pymetrozine	Carbosulfan
	Pirimicarb	Thiamethoxam
Least efficacy	Control (most survivors)	Acetamiprid (least survivors)

The efficacy rating of chemicals tested against aphids and beneficial insects in 2002/03 are given in table 3. These ratings are derived from the absolute values of the post-treatment means in table 2. Pirimicarb was found to be the least efficacious chemical against aphids in the trial. The effect of aphid resistance and beneficial tolerance to this product was clearly shown in these studies (Tables 2 & 3).

Comparing the pre-treatment aphid population with the average post-treatment population for the remainder of the season (averaged over 13 dates, i.e. 30 days trial duration), the most effective treatments against aphids were acetamiprid, carbosulfan, thiamethoxam and clothianidine. Imidacloprid, pyriproxifen and pymetrozine failed to adequately control aphids for the duration of the trial (Figs 1 and 2).

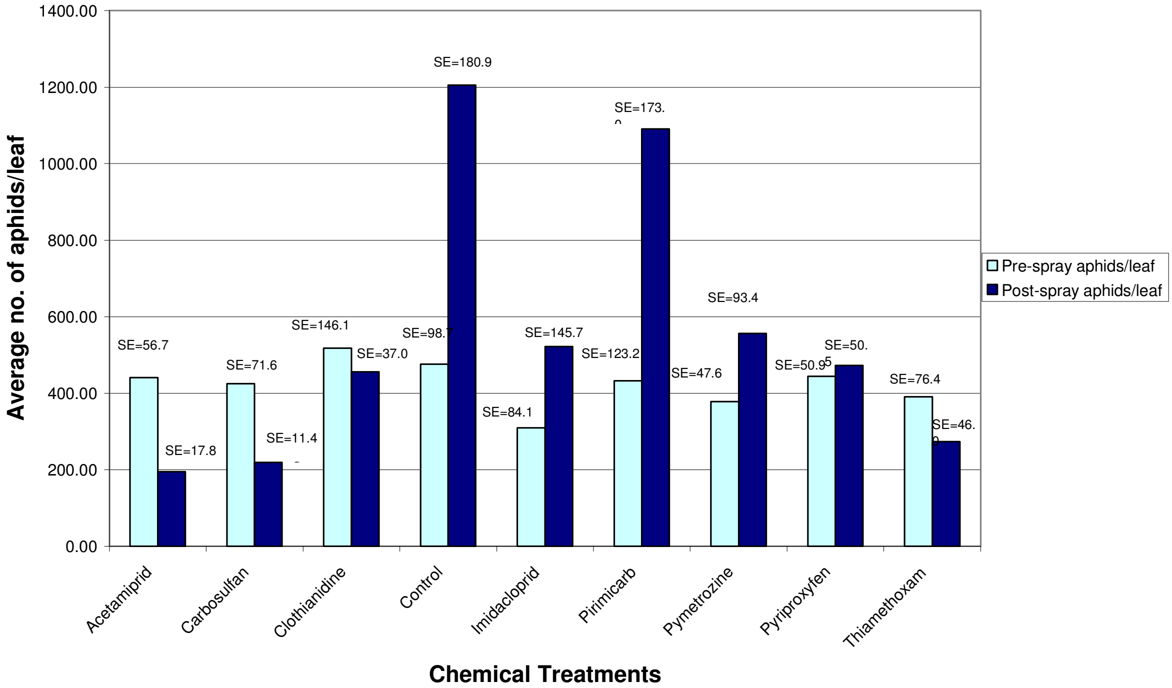

Figure 1: Efficacy of insecticides on aphids in cotton, ACRI 2002/03

Figure 2 shows that carbosulfan, pyriproxifen and acetamiprid suppressed aphid populations throughout the trial period. Aphid numbers reduced after the first application and again after the second application. The pirimicarb treatment did not affect numbers of aphids/leaf and was similar to the control plots. Imidacloprid, clothianidine and pyriproxifen did not have any effects on aphids until the second treatment application when numbers declined more markedly relative to the control (Figure 2)

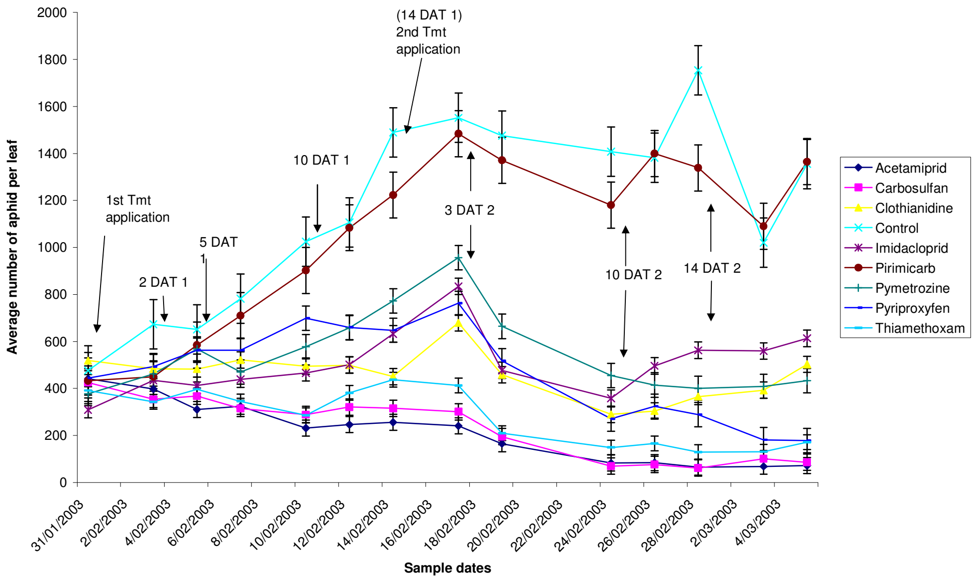

Figure 2: Efficacy of insecticides on aphids in cotton, ACRI 2002/03

2003/04 Helicoverpa trial

In the 2003/04 study Rimon and Gemstar were removed from trials and were replaced with Intrepid. The reason for the removal of Rimon and Gemstar were that Rimon was withdrawn from registration in cotton due to technical problems and Gemstar had been a commercial biological product for some time.

Results from Dvac samples showed that the number of jassids/m were significantly reduced by Azamax (19%) and Steward (19.9%) compared to the control. Steward had 43.8% less mirids and 57.4% less ADB than the untreated control plot (Appendix 2, Table 7). However, thrips numbers per metre were significantly higher on Steward treated plots (45.1%). In addition Steward reduced the number of 2 spotted ladybird (75%) and ants (45.1%) relative to the control (Appendix 2, Table 8). All the chemicals tested except Azamax significantly reduced the number of ants/metre but in general the number of ants were low in all treatnets. This could be explained by the fact that since ants attend aphids the low aphid numbers in this trial could account for the low numbers of ant. Despite this Steward treated plots had significantly more aphids than any other treatment (1.94 aphids/m). Wasp numbers were significantly reduced by BASF320 (26.9%) and Intrepid (28.6%) relative to the control (Appendix 2, Table 8). No other beneficial insect were significantly affected by any of the chemicals tested.

Visual counts of *Helicoverpa* showed that Steward and S1812 treatments had significantly higher numbers of Helicoverpa brown eggs than the untreated control. The number of brown eggs on the Steward plot was 104 and S1812 plots was 123 times higher than the control plot. Nevertheless the high number of brown eggs did not translate to Helicoverpa larvae/plot in these plots. The Steward plot recorded 84.5% and S1812 recorded78.2% less larvae than the control treatment. The BASF320 treated plots also recorded 84.5% less larvae than the control. Subsequently Steward, S1812 and BASF320 were very effective in controlling *Helicoverpa* spp.

Aphid trial

Aphids establishment in the trial plots during 2003/04 season was low as a result of rain and unfavourable weather conditions. As a result the number of aphids/leaf was generally low on all treated plots. In comparison, adult numbers were less than half of the numbers recorded in the previous season. Aphid resistance to pirimicarb was again confirmed with significantly higher numbers of aphids in the Pirimicarb treated plot than all the insecticide tested (Table 4). Acetamiprid, carbosulfan and thiamethoxam were the most efficacious treatments against aphids. These insecticides reduced adult aphid numbers by 48.5, 29.6 and 36.4%, respectively relative to the control. Chlothianidine and imidacloprid also recorded 35.8 and 32.1% aphid control respectively relative to the control plot. These effects were not reflected in the number of nymphs per leaf as their development was already impaired by biotic factors, except in the carbosulfan treatment, which had 23.4% less nymphs than the control treatment. The overall reductions in aphid numbers for the season are given in Figure 3. Numbers of beneficial per metre were reduced by acetamiprid (76.9%), carbosulfan (44.5%), and thiamethoxam (35.6%), pymetrozine (33.4%), chlothianidine (23.8%) and imidacloprid (22.1%) relative to the control plot.

Table 4: Mean abundance of aphids and beneficials in each insecticide treatment, ACRI 2003/04

Treatment	Aphids/leaf		Adults/leaf		Nymphs/leaf		Alatae/leaf		Beneficials/leaf	
	mean	%	mean	%	mean	%	mean	%	mean	%
Acetamiprid	107.69	-8.25	1.32	-48.53*	96.67	-13.16	9.70	178.18*	0.98	-76.87*
Carbosulfan	93.71	-20.15	1.81	-29.59*	85.26	-23.41*	6.65	90.67*	2.36	-44.48*
Clothianidine	98.01	-16.49	1.65	-35.84*	92.61	-16.80	3.75	7.67	3.24	-23.84*
Imidacloprid	99.52	-15.20	1.74	-32.09*	94.32	-15.27	3.46	-0.69	3.32	-22.06*
Pirimicarb	158.87	35.37*	3.32	29.27*	152.09	36.64*	3.46	-0.67	4.70	10.32
Pymetrozine	122.80	4.63	2.31	-10.10	116.32	4.50	4.16	19.49	2.83	-33.45*
Pyriproxifen	136.50	16.30	2.46	-4.17	129.47	16.32	4.56	30.90	4.06	-4.63
Thiamethoxam	111.23	-5.22	1.63	-36.37*	103.95	-6.62	5.65	62.21*	2.74	-35.59*
Control	117.37	0	2.57	0	111.31	0	3.49	0	4.26	0
df	294		294		294		294		294	
LSD(P=0.05)	24.29		0.54		23.31		1.33		0.870	

1. Values are means of data from washes
2. Values are percentage change compared to the control treatment
3. Asterisks in each column indicate treatments significantly different from the control at P=0.05.

In 2003/04 season there was less variation in beneficial insect numbers pre-spray and the effect on beneficials between pre- and post-spray averages was much more marked. Numbers increased significantly in every treatment over the duration of the trial (Table 5). The marked increases of insects on pyriproxifen, pymetrozine and pirimicarb similar to the control showed that these treatments had least effect on beneficials.

Table 5: Percentage increase in numbers of beneficial insects before and after treatment application, ACRI 2003/04.

Chemical	**% increase from control /leaf**
Acetamiprid	96.0
Carbosulfan	252.2
Thiamethoxam	274.0
Imidacloprid	564.0
Clothianidine	881.8
Pyriproxifen	1130.3
Control	1190.9
Pymetrozine	1564.0
Pirimicarb	2664.0

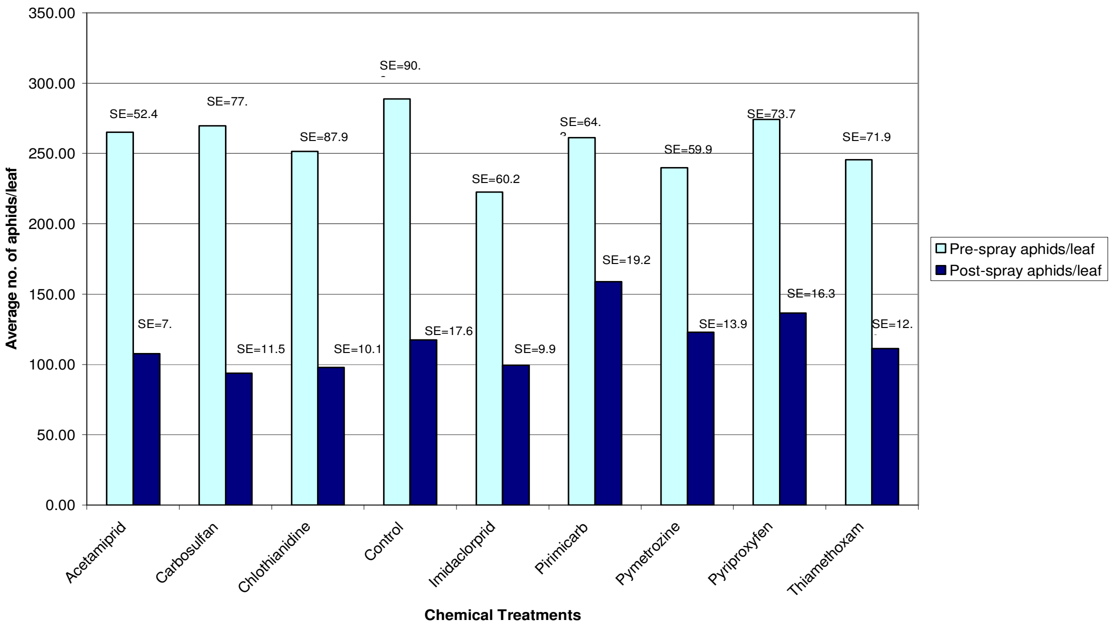

Figure 3: Efficacy of insecticides on aphids on cotton, ACRI 2003/04

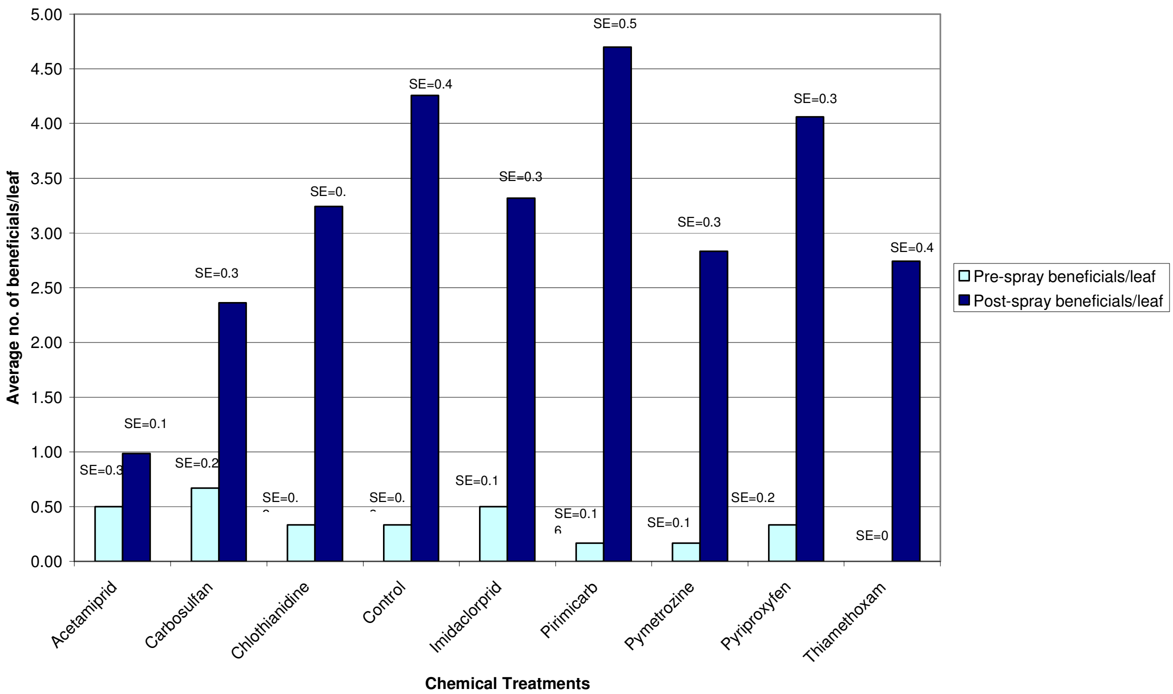

Figure 4: Efficacy of insecticides on beneficial insect populations in cotton, ACRI, 2003/04

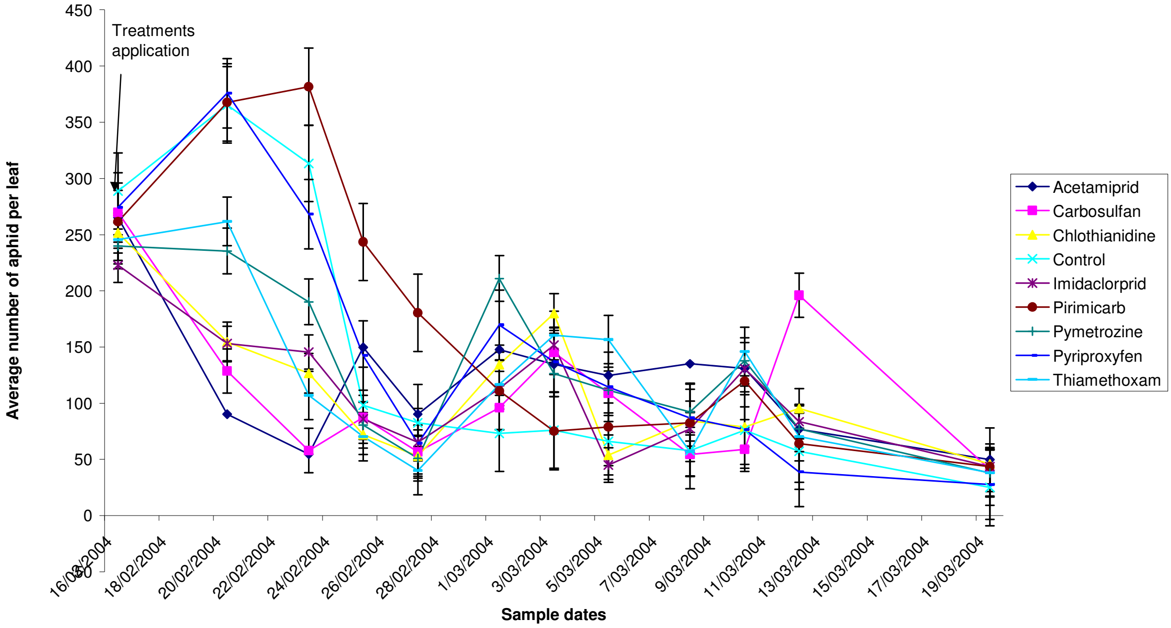

Figure 5: Efficacy of insecticides on aphids in cotton, ACRI, 2003/04

The effect of weather conditions can be seen clearly between the second and third sampling dates as aphid numbers dropped in all treatments. Immediately after the first spray the effectiveness of acetamiprid, carbosulfan and imidacloprid was apparent as aphid numbers in these treatments were reduced drastically. The reduction of aphids/leaf on thiamethoxam and clothianidine treated plots were slow. Aphid numbers fluctuated throughout most of the treatments for the rest of the season.

2004/05 Helicoverpa Trial

In this study high egg pressure occurred early in the season. The Bollgard II crop had 14.8% more eggs than the conventional cotton crop. However, the Bollgard II crops controlled 78 – 80% of the very small larvae. This means that the expression of the Bollgard II genes was very strong, proven by the total and significant lack of medium and small larvae for the variety. The Bollgard II gene expression is much stronger than in Ingard varieties. Despite the high egg numbers initially, the crop was well protected from larger larvae. In theory, virtually no larvae should survive on a Bollgard II crop, however, those smaller larvae that were found were likely counted shortly after hatching and before they fed sufficiently to poison themselves. This scenario is supported by the lack of medium and large larvae.

The D-vac sample analysis showed that Hemiptera sucking pests were mostly affected by the chemicals tested. Steward significantly reduced the number of thrips/m (40.7%) and aphids (95%) relative to the untreated control. In addition Steward reduced mirids by 34.6% and apple dimpling bugs by 36% relative to the control. Azamax, BASF320 and Endosulfan SC reduced the number of green mirids per metre by 32.5, 34.7 and 26% respectively relate to the control.In addition Endosulfan SCreduced whitefly population by 32.4% and ADB by 27% Endosulfan EC reduced ADB numbers per metre by 22% and jassids by 21.2% relative to control. Azamax was also effective to ADB reducing the population by 22%. Beneficial insects exception of ants and spiders were not affected by any of the chemicals tested. Both Endosulfan SC and EC all reduced the ant population by 62.6 and 54.2% respectively relative

to the control. In addition Endosulfan EC reduced the number of spiders per metre by 20.6%. In general all the insecticides tested reduced Helicoverpa spp. numbers except Abrade.

Table 6: Efficacy of insecticides on *Helicoverpa* spp. (suction samples)

Chemical Treatment Rating	Total *Helicoverpa* reduction	
Most efficacy	NNI 0001 SC	93.00%
↓	Endosulfan EC	84.52%
	Endosulfan SC	77.55%
	Steward SC	74.65%
	DPXKN 128 EC	58.22%
	Azamax	54.66%
	BASF 320	34.38%
	Abrade	28.50% n.s.
Least efficacy	Control	0.00

Visual bug checks showed that only brown eggs were affected, and only by Steward, which reduced their numbers by 27.89% compared to the untreated control. Very small and small larvae were significantly reduced by all chemicals except Abrade and BASF 320 while medium and large larvae showed significantly lower numbers for all chemical treatments (Table 7).

Table 7: Efficacy of insecticides on *Helicoverpa* spp. (bug checks)

Chemical Treatment Rating	%Reduction VS & S larvae		% Reduction M & L larvae	
Most efficacy	Steward SC	70.34%	NNI 0001 SC	97.16%
↓	NNI 0001 SC	64.87%	Endosulfan SC	94.32%
	DPXKN128 EC	53.03%	Steward SC	91.65%
	Endosulfan SC	50.03%	Endosulfan EC	91.48%
	Endosulfan EC	46.47%	DPXKN128 EC	85.96%
	Azamax	41.14%	BASF 320	50.21%
	BASF 320	26.36% n.s.	Azamax	47.66%
	Abrade	6.44% n.s.	Abrade	33.56%
Least efficacy	Control	0.00	Control	0.00

DPXKN128 EC and Steward SC were both equally effective against *Helicoverpa*. DPXKN 128 treated plot recorded lower number of thrips and jassids than Steward SC but was less effective against mirids. DPXKN 128 was also effective on other *Hemiptera* spp. In addition the product was less toxic to ants, spiders, wasp and other coleopteran predatory insects similar to Steward.

Aphid trial

Table 8 shows the number of aphids, mites and beneficial insects recorded in each of the insecticides tested and control treatment. A high rate of parasitism was also observed as the season progressed but this did not seriously interfere with the trial.

Carbosulfan, thiamethoxam, pymetrozine and acetamiprid provided the most effective control of aphids but they also had the greatest impact on beneficial insect population reducing their numbers by 40-60 % (Table 8). Pyriproxifen caused only 16.6% control of aphid where as aphid population effective on the pirimicarb treated plots increased by 20.8% relative to the pre-treatment counts.

Table 8: Mean abundance of aphids, mites and beneficial insects in each insecticide treatment, ACRI 2004/05

Treatment	Aphids/leaf		Adults/leaf		Nymphs/leaf		Mites/leaf		Beneficials/leaf	
	mean	%	mean	%	mean	%	mean	%	mean	%
Acetamiprid	634.10	-47.66*	70.68	-57.75*	530.52	-46.98*	2492	48.04*	11.31	-39.52*
Thiamethoxam	543.42	-55.14*	53.43	-68.06*	454.97	-54.53*	2811	67.0*	9.80	-47.62*
Pyriproxifen	1010.04	-16.63	129.15	-22.79	836.86	-16.36	1770	5.16	16.88	-9.77
Clothianidine	845.45	-30.21*	129.81	-22.39	678.24	-32.21*	2150	27.73*	12.27	-34.42*
Imidacloprid	841.61	-30.53*	116.07	-30.61*	688.92	-31.15*	2179	29.44*	10.03	-46.37*
Pymetrozine	556.10	-54.10*	57.74	-65.48*	468.23	-53.20*	1866	10.83*	8.31	-55.56*
Carbosulfan	363.58	-69.99*	34.88	-79.15*	308.11	-69.21*	2568	52.57	7.56	-59.57*
Pirimicarb	1464.03	20.85*	177.18	5.93	1231.09	23.04*	1706	1.34	21.47	14.79
Control	1211.47	0	167.27	0	1000.55	0	1683	0	18.70	0
df	429		429		429		429		429	
LSD(P=0.05)	209.9		38.14		182.5		10.13		3.33	

1. Values are means of data from washes
2. Values are percentage change compared to the control treatment
3. Asterisks in each column indicate treatments significantly different from the control at P=0.05

Table 9: Efficacy rating of insecticides for aphid control on cotton, ACRI 2004/05

Rating for aphid control	Treatment	% change from Control
Best Control	**Carbosulfan**	-70.00
	Thiamethoxam	-55.14
	Pymetrozine	-54.09
	Acetamiprid	-47.65
	Imidacloprid	-30.53
	Clothianidine	-30.21
	Pyriproxifen	-16.62
	Control	0.00
Worst Control	**Pirimicarb**	20.84

Note: Each colour coded group is significantly different from each other except for pyrproxifen which is not significantly different from both the control and clothianidine.

In every cotton field there is a competition for resources between mites and aphids as well as interaction between predators and prey. This was clearly observed in the aphid trial this year. As parasitic wasps increased, the aphid population decreased. This would have been promoted by chemicals that were softer on beneficials but hard on aphids. Pirimor and pyriproxifen had least impact on wasps (signified by mummies) and maintained the highest number of beneficials. Since they also had no significant impact on aphid and mite control, these treatments then provided more prey for beneficials. Conversely, a reduction in aphid numbers and beneficials gave better opportunities for mite populations to increase. Hence, the better aphid treatments such as carbosulfan, thiamethoxam, acetamiprid and imidacloprid also had the highest mite numbers. Clothianidine, while not quite as effective on aphids as imidacloprid, had a similar effect to imidacloprid on mites, wasps and beneficials. Figures 6-9 show the pre-spray counts against the seasonal averages for aphids, mites, beneficials and mummies.

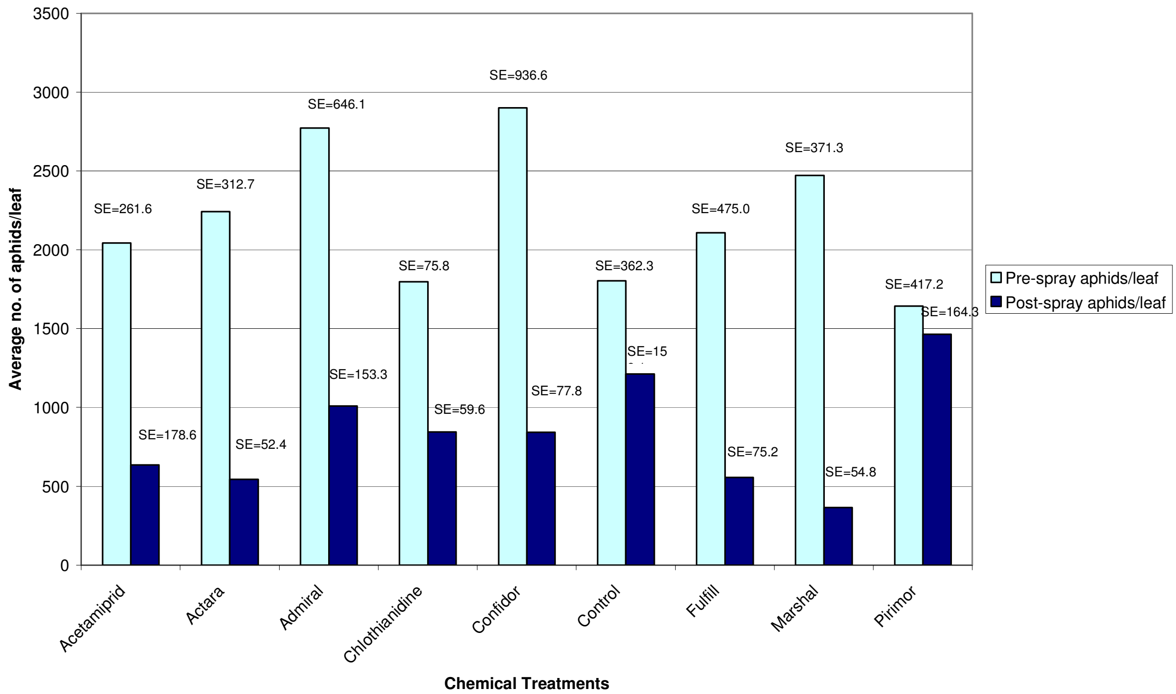

Figure 6: Efficacy of insecticides on aphids in cotton, ACRI 2004/05

Aphid numbers fell over the season, a reflection of spraying, parasitism and increases in mite numbers.

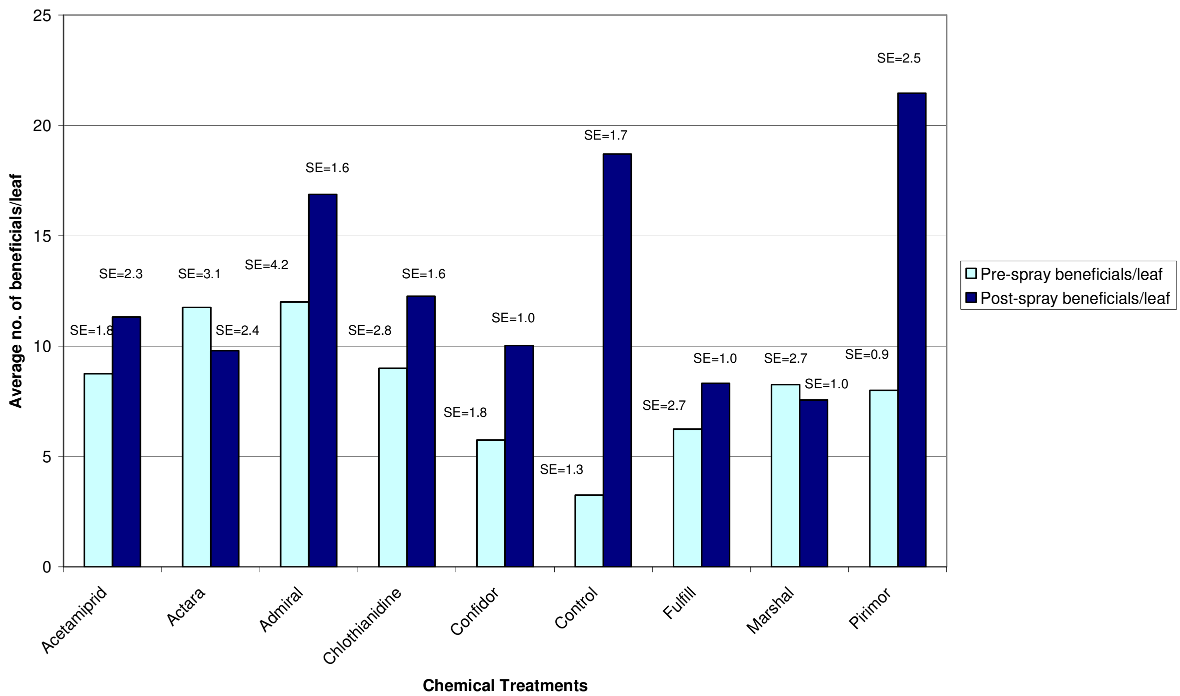

Figure 7: Efficacy of insecticides on beneficial insects in cotton, ACRI 2004/05

The beneficial populations increased overall but were affected by sprays. Thiamethoxam and carbosulfan had the greatest impact, reducing beneficial numbers by 16.68% and 8.36%, respectively, when compared to controls, which increased by 475.47%. While still quite effective on aphids, imidacloprid was also softest on beneficials, allowing for a 74.43%

increase when considering the seasonal post-spray average. Beneficials in the pirimicarb plots increased by 168.25% while those in the acetamiprid, pymetrozine, clothianidine and pyriproxifen plots increased between 29.25% and 40.58%.

All treated plots showed large increases in mite numbers for the season. Mite numbers in the pirimor, pymetrozine, pyriproxifen treated and the untreated control plots were still significantly lower than those in carbosulfan, acetamiprid, thiamethoxam, imidacloprid and clothianidine treated plots. Differences were observed in the rate of increase of mites with thiamethoxam, carbosulfan and acetamiprid plots showing the fastest increase and greatest amount of leaf reddening.

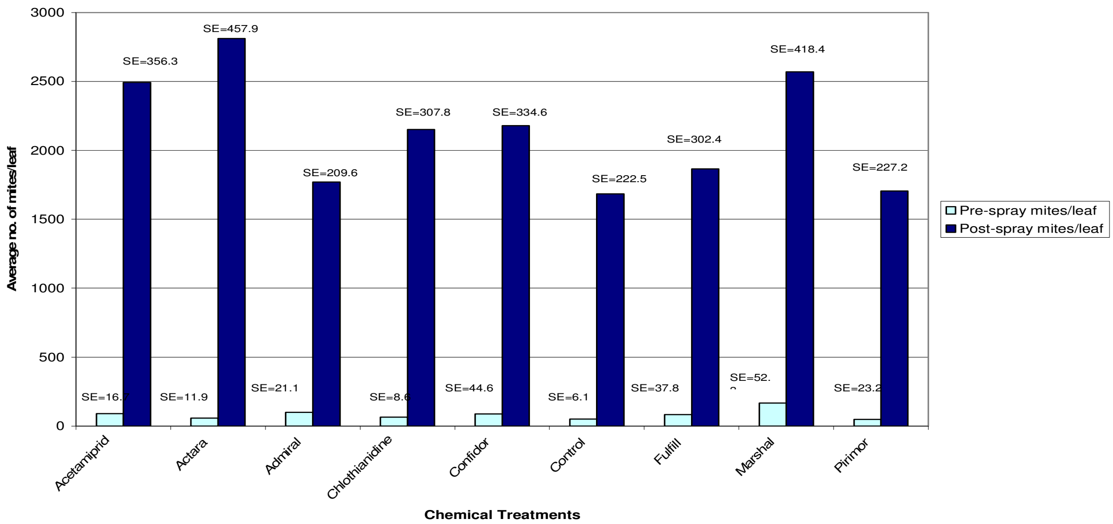

Figure 8: Efficacy of insecticides on mites in cotton, ACRI 2004/05

Wasp parasitism was highest in the control, pirimor and pyriproxifen treatments, which also had the most aphids. The lowest number of mummies occurred in the carbosulfan and thiamethoxam treatments indicating their effectiveness as aphidicides, and also their detrimental impact on aphid parasitoids.

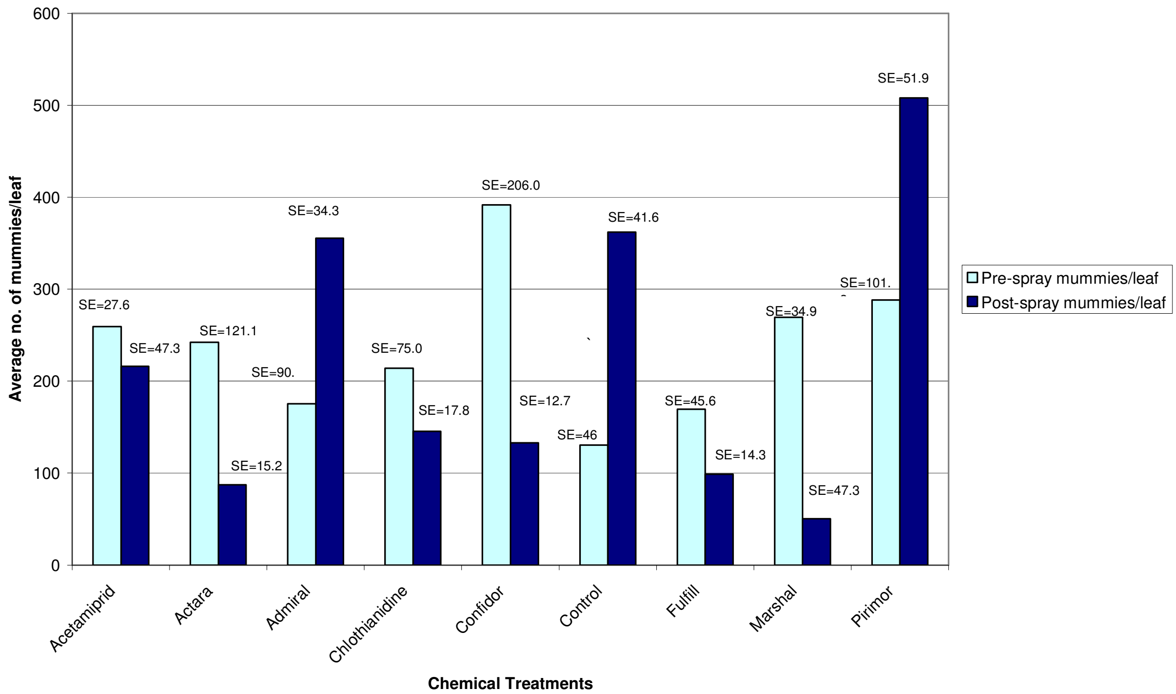

Figure 9: Efficacy of insecticides on wasp parasites of aphid in cotton, ACRI 2004/05

The number of aphid per leaf were unaffected by the Pirimor and Pyriproxifen treatments and numbers rapidly increased on these treated plots similar to the control treatment (Figure10). They all showed a natural decline after the third sampling date, which persisted for the remainder of the trial. Acetamiprid, thiamethoxam, pymetrozine, carbosulfan, confidor and clothianidine remarkedly reduced aphid numbers. After the third sampling date the decline continues in line with the decreasing aphid population across the field. Eight to fourteen days after the initial treatment, aphid populations rose again except in the thiamethoxam, carbosulfan and pyriproxifen treatments which kept aphid numbers consistently low (Figure10).

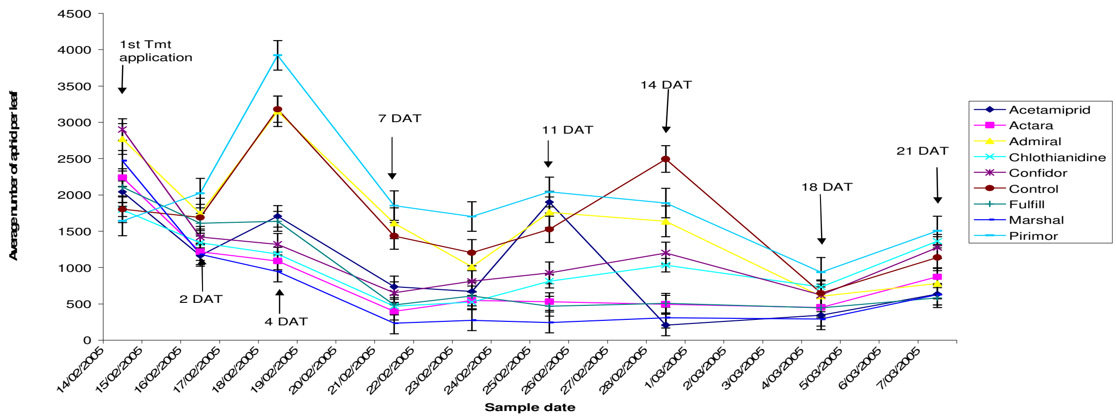

Figure 10: Efficacy of insecticides on aphids in cotton, ACRI 2004/05

Conclusion

(i) Efficacy of new insecticides for controlling Helicoverpa spp.

- Low numbers of *Helicoverpa* in the field between 2002 and 2004 were a major problem reducing the reliability of results
- Better information from the 2004/05 season
- Bt toxin gave the best protection against *Helicoverpa* damage
- Both Steward and S1812 significantly reduced large *Helicoverpa*
- During the last season all tested chemicals except Abrade significantly reduced *Helicoverpa* numbers.
- Steward controlled both egg and larval stages while all other chemicals controlled only larvae.
- NNI 0001, Endosulfan SC and DPXKN128 were very effective on very small and small larvae while NNI 0001 and both the SC and EC formulations of endosulfan were most effective against medium and large larvae
- The most efficaceous chemical options for *Helicoverpa* control were Steward, S1812, NNI 0001 followed by moderately efficacious chemicals such as Endosulfan EC, BASF320 Gemstar, DPXKN128 and Azamax while lower efficacy was seen in Rimon and Abrade.

(ii) Efficacy of new insecticides for controlling aphids in transgenic cotton

- Best control options for aphids were thiamethoxam, carbosulfan (foliar formulation), acetamiprid and pymetrozine which were indiscriminate and also reduced beneficials
- Imidacloprid and clothianidine both showed medium capacity to control aphids and beneficials alike
- Pyriproxifen and pirimicarb had the least impact on both aphids and beneficials
- While there is a known resistance to pirimicarb in most aphid strains, the ineffectiveness of pyriproxifen relates to its mode of action, which does not appear to affect aphids.
- Chemicals that were very effective in controlling aphids have to be placed at the right position during the growing season. For example, during the last stage of the cotton crop when bolls have already opened carbosulfan can be used effectively to wipe out any late aphid population and leave no residue by harvesting time. New insecticides with distinct characteristics allow a better insecticide selection for aphid control in future. Acetamiprid, a neonicotinoid insecticide, registered by DuPont for controlling aphids was one of the best performing insecticides in this season's trial.
- Bollgard II varieties are unlikely to require early season sprays for *Helicoverpa* control as the Bt toxin does not allow for the development of a full life cycle at this stage. Hence there would be no co-incidental control of early aphids. Aphid populations rarely become economically significant until mid December, unless there

is a flare up of Cotton Bunchy Top (CBT) infections. Therefore, early aphid sprays are likely unnecessary.

- If the crop is unsprayed, large numbers of predators should be building up by December that will keep aphid populations in check. Later in the season, parasitic wasps are very effective control agents.
- Control for mirids may be required and chemicals that depress beneficials will also affect the development of aphid populations. It is therefore important to choose the chemicals with the least impact on aphid predators.
- All data from these trials has been incorporated into the Cotton Management Guidelines.

(iii) Assess the impact of new chemistries on other pest and beneficial insects

- Abrade which was supposedly effective on Lepidoptera larvae, had no effect on this group but promoted some Hemiptera pests and reduced some beneficial Coleoptera. The proposed mode of action of cutting into insect membranes and having a repellent effect was not obvious.
- Three chemicals consistently stood out for mirid control: Steward, Rimon and BASF 320. Azamax and Endosulfan SC also significantly reduced this pest. Steward was the overall choice for the reduction of sucking pests including jassids and apple dimpling bugs; however, it was not very effective against thrips and was hard on some beneficials. Both BASF 320 and Intrepid negatively affected wasp numbers while Endosulfan formulations reduced ants.
- Any pest and beneficial species not mentioned here were not significantly affected by the tested chemicals. This was either due to low numbers of these species in the field or due to the nature of the chemical.
- During the 2004/05 season, large numbers of predators were observed in the aphid trials, especially pirate bugs, coccinellids, lacewing, syrphid and chamaemyiid fly larvae. Most of these were negatively affected by the chemicals used.
- The sampling methods employed in this trial (leaf washes) did not allow for sampling of faster beneficial species that are usually caught in a suction sampler and can therefore only refer to aphid predators.

Outcomes

Despite the introduction of transgenic cotton crops in the Australian cotton Industry, cotton growers will continue to grow conventional cotton crops. As a result new insecticides need to be developed to support IPM on cotton. Therefore the testing of the efficacy of new insecticides will assist in placing these insecticides in the Integrated Pest Management Guidelines and the update of the Insect Resistance Management strategies. Data on the impact of these new insecticides on pest and beneficial insects will assist IPM and IRMS researchers to update their knowledge in new insecticide tools for IPM and IRMS guidelines. In addition the information will help growers and consultant in selecting insecticides. Making a good selection will result in a reduction of insecticide applications, optimising beneficial insects and supporting IPM programs. Furthermore strategic use of new insecticides will avoid the resistance build up and prolong the life span of these chemistries. There are also financial and environmental incentives in reducing insecticide applications. Economically, the reduction in insecticide use due to a more strategic use of insecticides will impact on the production costs of growers and may lower the costs for the insect pest control component of cotton growing. By working towards a reduction in insecticide use and also using softer selective options, it will reduce the overall environmental impact of pesticides on the environment and on other industries.

Project Summary

Technical advances

The project was designed to evaluate the efficacy of new chemical formulations on target and non-target pests and beneficial insects. While performance of some chemicals in the control of mirids and aphids were outstanding they also had negative effects on beneficials. The information generated by this project was made available to the chemical suppliers. The information could assist in revising a rate recommendation when registering the product for use in cotton. During the duration of the project, Dupont registered acetamiprid for control of aphids in cotton. This project has repeatedly shown that the Steward SC formulation of indoxacarb, although very effective on the target pest, has been detrimental to many beneficials. It is a very positive outcome to see that Dupont has acknowledged this by testing a new formulation of this chemical (DPXKN 128EC) that is hopefully softer on beneficials.

Methoxyfenocide (Prodigy) was also registered by Nufarm for use against *Helicoverpa* in cotton during the project while novaluron (Rimon) was withdrawn from registration due to technical problems. Bayer developed the foliar SC formulation of carbosulfan rather than the soil applied EC formula for better efficacy and it has proven as one of the most effective aphidicides in the trial. Both pymetrozine (Fulfill) and thiamethoxam (Actara) by Syngenta have been very effective on aphids and have also been registered for this purpose.

While pyriproxifen (Admiral) is one of the best chemicals against whiteflies it did not work particularly well on aphids in these trials. The trials showed that Pirimicarb has become completely ineffective on the aphid strain reared for this trial. This reflects how a very good and selective chemical has been lost due to insect resistance.

With respect to equipment design, the 8-line spray rig (Spraying Mantis), which was specially built for this type of trial has proven to be a most effective application tool. It applies 8 different chemicals in one spray operation, thereby saving time and reducing compaction of the field. It also ensures even application of the various treatments.

.

Plan for activities beyond the project

The project technology and sampling procedures are successful. The way the project has been set up allows for flexibility in testing a variety of chemicals on a variety of pests. For example, the spray rig was taken to Emerald during the recent whitefly outbreak to test various insecticides for control of this pest. However, outcomes in the long term rely on a continuation of this type of work. While most insects are currently controllable with IPM techniques and the current pool of registered chemicals, the development of resistance is a gradual but constant process. This provides windows for chemical companies to develop new products. To be able to evaluate and compare these new products and know where to place them in the IPM guidelines, we need to continue this work. The information generated by this project also appears in the IPM support document which helps growers and consultants to decide which chemical is the most suitable one for a particular situation. The decision on where to place a particular chemical in the Insecticide Resistance Management Strategy (IRM) timetables is made by consultants, scientists and growers during annual meetings. These decisions are based on having adequate information about the effectiveness of a chemical and its impact on beneficials. To produce the data is a time consuming process and must be in line with registration of a product. Any questions cannot be answered on demand if the research has not been done prior to registration.

Recommendations

This type of work, while appearing repetitive and schematic, has yielded useful and valuable information which also needs to be provided in future. Since the introduction of Bollgard II cotton in 2003/04, the pest situation has once again shifted and brought up new uncertainties with respect to *Helicoverpa* tolerance thresholds in GM crops. Specifically, growers and consultants are uncertain about potential damage on Bollgard II when there are heavy *Helicoverpa* egg lays. Also, with less early sprays in Bollgard II crops, the need for specific control of sucking pests and the preservation of beneficial is more critical for growers. Hence this type of project contributes to clarify some specific issues relating to pest management and beneficial preservation in GM cotton and outcomes in the long term rely on a continuation of this type of work. However, as chemicals become dated and obsolete, so does the information. Because the information generated by this work helps to place new chemicals into the IPM strategy guidelines it is very important that it remains current. Producing this type of data is a time consuming and labour intensive process but to be useful, it has to keep up with the development and registration of new products.

Publications

Due to the confidentiality nature of the work with unregistered formulations supplied by various chemical companies, there is limited chance of publishing this type of work. However, as soon as any tested chemical becomes registered, the relevant information generated by this trial has been included in the update of insecticide information in the Cotton Management Guidelines handbook. Also plan to published work done on the newly registered chemical, acetamiprid.

Impact on the Australian Cotton Industry

The results from this research have been communicated to researchers, growers or industry through presentation, report or personal communications in workshops or meetings. For example, presentation at ACRI research seminars. They are also presented as part of the hands-on research sessions of the Australian Cotton Conference. Reports on the various tested chemicals have been sent to the respective company representatives and can be used to refine their application rate recommendations. Students are also made aware of the research and its impact during the Cotton IPM course run by Mark Hickman.

This research will contribute to the reduced use of insecticides in the cotton industry by permitting better strategic choices of chemicals for growers and consultant. The optimum use of chemicals in IPM systems can be based on the independent information supplied by this project. Insecticide applications can be reduced either by the actual reduction of given rates

for specific purposes or by eliminating the use of additional sprays by using existing beneficial insects in the crop.

Socially this project is part of a bigger picture and works towards a sustainable cotton industry that can offer employment and financial rewards to local communities and also reduce its impact on such communities.

Sustainability – This project will contribute to the extended use of certain chemicals for pest control in the industry. It therefore enables growers to make decisions based on best management practices which also reduce the environmental impact of spray operations.

References

Cowgill, S. E. and Bhagwat, V. R. 1996, Comparison of the efficacy of chemical control and Helicoverpa armigera (Hubner) on resistant and susceptible chickpea. Crop Protection Vol.15 No.3 pp 241-246, Elsevier Science Ltd.

Fitt G. P. 2000, An Australian approach to IPM in cotton: Integrating new technologies to minimise insecticide dependence. Crop Protection, 19, 793-800 Elsevier Science Ltd

Forrester, N., Holloway, J., 1998 New Insecticides chemistry for Australian cotton. In: Swallow, D. (Ed.), Proceedings of 9th Australian
Cotton conference ACGRA, Wee Waa. Pp603-610

Mensah, R.K., 2002. Development of an integrated pest management programme for cotton. Part2: Integration of a lucerne/cotton interplant system, food supplement sprays with biological and synthetic insecticides. International Journal of Pest Managementt, 2002 48(2) 95-105.

Wilson, L. J., Bauer, L. R., Lally, DA., 1998 Effect of early season insecticides use on predators and outbreak of spider mites
(Acri:Tetranychidae) in cotton. Bull. Entomol.Res. 88, 477-488

Wilson, L. and Spora, A. 2001 Aphids in Cotton. Research Review, Australian Cotton CRC , No.10, Dec. 2001.

Part 4 – Final Report Executive Summary

In 2002/03 these chemicals were tested for *Helicoverpa* species control: Abrade® 50% a.i. (Grow Choice Pty. Ltd), Azamax® 1% a.i. (OCP Pty. Ltd.), BASF320 200g a.i. (BASF), Gemstar® (Bayer Cropscience), Prodigy® 240g/L a.i. (Dow Agrosciences), Rimon® 100g/L a.i. (Nurfarm), S1812 50% a.i. (Sumitomo) and Steward® 200 g/L (Dupont). In 2003/04 the same set of insecticides was used with only one change where Gemstar® was dropped and Intrepid® was included. During 2004/05 season Abrade®, Azamax®, BASF320 and Steward® SC were still included plus new formulation such as DPXKN128 EC, Endosulfan®SC and NNI-0001SC.

***Helicoverpa* Control:** Bt toxin gave the best protection against *Helicoverpa* damage. Both Steward and S1812 significantly reduced large *Helicoverpa*. During the last season all tested chemicals except Abrade significantly reduced *Helicoverpa* numbers. Steward controlled both egg and larval stages while all other chemicals controlled only larvae. NNI 0001, Endosulfan SC and DPXKN128 were very effective on very small and small larvae while NNI 0001 and both the SC and EC formulations of endosulfan were most effective against medium and large larvae. The most efficaceous chemical options for *Helicoverpa* control were Steward, S1812, NNI 0001 followed by moderately efficacious chemicals such as

Endosulfan EC, BASF320 Gemstar, DPXKN128 and Azamax while lower efficacy was seen in Rimon and Abrade.

New chemistry insecticides tested against *Aphis* spp. control were the same for 2002/03, 2003/04 and 2004/05. It includes, Acetamiprid – Intruder® 225g/L a.i. (Dupont), Carbosulfan – 'new Marshal' 250 g/L a.i. (Crop Care), Clothianidine – TI-435 16% a.i. (Sumitomo), Imidacloprid – Confidor® 200g/L a.i. (Bayer Cropscience), Pirimicarb – Pirimor® 500g/L a.i. (Syngenta), Pymetrozine – Chess® 500g/L a.i. (Syngenta), Pyriproxifen – Sumilav® 20g/L a.i. (Sumitomo) and Thiamethoxam – Actara® 250g/L a.i. (Syngenta).

Aphid Control: Best control options for aphids were thiamethoxam, carbosulfan (foliar formulation), acetamiprid and pymetrozine which were indiscriminate and also reduced beneficials. Imidacloprid and clothianidine both showed medium capacity to control aphids and beneficials alike while Pyriproxifen and pirimicarb had the least impact on both aphids and beneficials. There is a known resistance to pirimicarb in most aphid strains but the ineffectiveness of pyriproxifen relates to its mode of action, which does not appear to affect aphids. Acetamiprid, a neonicotinoid insecticide was one of the best performing insecticides in this season's trial.

Effects on beneficial insects and non-targets: Abrade promoted some Hemiptera pests and reduced some beneficial Coleoptera. Three chemicals consistently stood out for mirid control: Steward, Rimon and BASF 320. Azamax and Endosulfan SC also significantly reduced this pest. Steward was the overall choice for the reduction of sucking pests including jassids and apple dimpling bugs; however, it was not very effective against thrips and was hard on some beneficials. Both BASF 320 and Intrepid negatively affected wasp numbers while Endosulfan formulations reduced ants. During the 2004/05 season, large numbers of predators were observed in the aphid trials, especially pirate bugs, coccinellids, lacewing, syrphid and chamaemyiid fly larvae. Most of these were negatively affected by the chemicals used.

This project has provided unbiased information for a number of new insecticides for *Helicoverpa* and aphid management, and their impact on key beneficial insects, in conventional and Bollgard II cotton varieties. The outcome was information that showed how best to place insecticides in IPM systems. Field data from this project is also an early indication of the impact of resistance on field performance of insecticides. Some of these results corresponded with laboratory data from a study carried out by Dr. Grant Herron (NSWDPI) on aphid resistance. The impact of this resistance was illustrated in these field trials where poor performance was seen with Pirimicarb®. This information provides clear evidence of the correlation between resistance data and field performance. The information also provided confidence in the use of field resistance test kits developed for aphids. The testing for chemical efficacy and non-target effects has been invaluable in creating the IPM guideline tables that provide growers with information to a) make a choice of the optimum chemical for a situation and b) find the optimum position for a particular insecticide within the IPM programs and resistance management strategies.