SULFOXAFLOR FOR MANAGEMENT OF COTTON PESTS IN AUSTRALIA

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Abstract

The introduction of transgenic cotton in Australia caused a dramatic shift in the importance of insect pests: chewing pests became less important while the sucking pests green mirids (*Creontiades dilutus)* and cotton aphid (*Aphis gossypii*) became the key pests in pest management regimes. *C. dilutus* adults and nymphs attack cotton causing reduced yield and lint quality, while *A. gossypii* vector viruses and cause the reduction of lint quality. Control of both *C. dilutus* and *A. gossypii* is primarily achieved through the use of disruptive insecticides which have shown a history of resistance development in a range of insect pests including sap feeding insect pests. Sulfoxaflor is a new broad-spectrum sap-feeding insecticide, which is effective at low use rates, is fast acting, has residual activity and is non-disruptive to beneficial insects. Extensive testing has demonstrated no cross-resistance between sulfoxaflor and any other insecticide class. Nine small-plot replicated field trials are presented in this paper. These data show that sulfoxaflor gave excellent initial and residual control of both *C. dilutus* and *A. gossypii* at 48 to 72 g ai/ha. Sulfoxaflor will be a valuable tool for Australian cotton growers following its anticipated registration in 2012.

Introduction

In Australia the introduction of transgenic cotton and subsequent dramatic reduction in insecticide sprays for chewing insect pests resulted in a dramatic increase in the importance of sap feeding pests, especially green mirids (*Creontiades dilutus*) and aphids. The cotton aphid (*Aphis gossypii*) is the key aphid pest species in Australian cotton with the cowpea aphid (*A. craccivora*) and green peach aphid (*Myzus persicae*) of lesser importance (Wilson *et al.,* 2008). *C. dilutus* adults and nymphs pierce plant tissue and release a chemical that destroys cells in the feeding zone. In cotton, growing points can be killed with squares, buds, flowers and small bolls shed, decreasing yield potential. When growing tips are damaged, plants branch and become difficult to manage. Boll feeding by green mirids can reduce lint yield and quality. Lygus bugs are in the same insect family (Miriidae) and damage caused by *C. dilutus* to cotton is very similar to that caused by *Lygus* spp. in the USA and other parts of the world. Aphids have the potential to cause substantial loss to the cotton grower. Early infestations can significantly reduce yield if not controlled adequately. Aphids are a confirmed vector for Cotton Bunchy Top syndrome, a virus-type disease of cotton. Cotton Bunchy Top causes stunting in cotton including reduced leaf and fruit size and reduced internode and petiole length which significantly impacts yield. Aphids also cause contamination of the cotton lint at the end of the season with sugary honey-dew discoloring the lint (Wilson *et al.,* 2008). With the rise in importance of sap-feeding pests in Australian cotton, their control has created new problems for the industry.

C. dilutus and *A. gossypii* are primarily controlled with insecticides. This general reliance on insecticides for pest management often causes disruption of beneficial insects and the overuse of insecticides with the same mode of action may promote insecticide resistance. Resistance in aphids to the most commonly used groups of insecticides in Australia and around the globe is well documented (Wilson *et al.,* 2008). Cotton aphids are prone to the development of resistance as they reproduce asexually in cotton systems. This means that all the progeny of a resistant individual will be clones and thus will be resistant. Once resistance is selected in a population it can quickly dominate. Due to the current pest status of aphids with documented resistance to currently used insecticides, it is critical to the cotton industry that new effective insecticides with novel modes of action are developed.

Sulfoxaflor is a new broad-spectrum sap-feeding insecticide. Extensive trial work carried out around the world has shown sulfoxaflor has very good activity on most sap feeding insects including: aphids (Hemiptera: Aphidoidea), plant bugs (Hemiptera: Miridae), soft and hard scales (Hemiptera: Coccoidea), mealybugs (Hemiptera: Pseudococcidae) and whiteflies (Hemiptera: Aleyrodidae) and some activity on thrips (Thysanoptera). In trial work, sulfoxaflor has demonstrated rapid contact activity as well as systemic residual activity on sap-feeding insects. Sulfoxaflor has shown little or no activity on chewing insects such as lepidopteran and coleopteran insects, as well as mites and nematodes at rates used to control sap feeding insects. Sulfoxaflor is the first insecticide to be developed from the sulfoximines, a new class of chemistry, discovered by Dow AgroSciences scientists (Zhu *et al.,* 2010). The first field development tests of sulfoxaflor in Australia began in 2006. Sulfoxaflor has a unique interaction with the nicotinic acetylcholine receptor (nAchR) (Watson *et al*., 2011). Relative to neonicotinoids, it has low affinity for the imidacloprid binding site, but is a high efficacy agonist of the nAchR. Furthermore, sulfoxaflor does not appear to be metabolized by monooxygenase enzymes that are responsible for most cases of neonicotinoid resistance in the field. Extensive testing has demonstrated no cross-resistance between sulfoxaflor and neonicotinoids or other insecticide classes (Zhu *et al.,* 2010). Sulfoxaflor will be a critical tool for insect resistance management for cotton growers. It is a new active with a new mode of action and it is effective on insect populations resistant to neonicotinoid and other insecticides.

Integrated pest management (IPM), where all crop protection methods are considered rather than solely relying on insecticides, is entrenched in Australian cotton production. Predators of *C. dilutus* in cotton are recorded as big-eyed bugs, predatory shield bugs, as well as lynx, night stalker and jumping spiders (Whitehouse *et al.,* 2011). *A. gossypii* is attacked by a range of parasitoids and predators including: ladybird beetle larvae, damsel bugs, big-eyed bugs and the larvae of green lacewings and hoverflies. Many of the insecticides currently used for control of *C. dilutus* and *A. gossypii* (including neonicotinoids, carbamates, synthetic pyrethroids, organophosphates and fipronil) are disruptive to these beneficial insects, especially early season use of the organophosphate dimethoate and pyrethroids. The introduction of beneficial insect-safe insecticide will facilitate the continued adoption of IPM in Australian cotton.

The beneficial insect profile of sulfoxaflor has been studied in Australia and the results show that sulfoxaflor has a favorable beneficial insect profile at proposed field use rates although increasing rates had an increasing negative effect. Sulfoxaflor tested at the highest proposed field rate of 96 g ai/ha had a very low effect on spiders, a low effect on wasps, and predatory beetles, a moderate effect on thrips, predatory bugs and Trichogrammatids and a high effect on thrips, ants, apple dimpling bugs and lacewings. The effects of sulfoxaflor on beneficial insects were reduced as the rate of sulfoxaflor was reduced (Wilson and Heimoana, unpublished 2011).

Nine field trials are presented in this paper. Five trials investigating the efficacy of sulfoxaflor on *C. dilutus* in Australia and four trials completed on *A. gossypii*. These data show that sulfoxaflor gave excellent initial and residual control of both *C. dilutus* and *A. gossypii* at 48 to 72 g ai/ha (200 to 300 mL/ha Transform™ Insecticide). Transform at 48 to 72 g ai/ha will be registered in Australia for both pests, with the higher rate needed when *C. dilutus* numbers are high and extended residual control of aphids is desired, for instance at the critical time in the crops' development as bolls open through to harvest and when there is 'zero tolerance' to aphids in the cotton crop.

Materials and Methods

Experiments were carried out between 2008 and 2010 across the important cotton growing areas in Australia (New South Wales and Queensland). All trials were small-scale randomized complete block trials with four replications and an included untreated control treatment. Plot sizes were adequate to allow accurate treatment application and the assessment of pests (generally 2-4 m x 10 m plots). Treatments are listed below in Table 1. Trial details are shown below in Table 2 and Table 3. Treatments were applied using a variety of application set-ups in order to simulate commercial practice as much as possible, using precision small-plot sprayers (pressurized AgMurf or Azo precision small-plot sprayer) (see Table 2). Applications targeted high infestations of *C. dilutes* and *A. gossypii* and were applied under good environmental conditions. *C. dilutus* is a difficult pest to assess reliably because it is highly mobile and moves around the crop quickly making counting difficult. All trials were assessed for knock-down 1-4 days after application and residual control at 7 day intervals from 7 to 28 days after application. Exact assessment timing varied at each trial. Assessments on *C. dilutus* were made using a beat sheet method, where a section of crop is pushed rigorously onto a yellow canvas sheet and the insects shaken onto the canvas counted before they have a chance to fly or jump away. This is a generally accepted assessment methods for mirids in Australian cotton. All data is presented as mirids per metre of crop row. Wingless *A. gossypii* were counted on 10-20 randomly selected leaves or tagged leaves (104005RA) depending on the trial. The maximum manageable number of leaves was counted in order to generate reliable and robust data. All data is presented as aphids per leaf. Data were transformed as needed based on analysis of homogeneity of variance (Bartlett's test) by log (x+1) or Arcsine square root percent(x) to normalize prior to analysis and means were separated using Tukey's HSD (P=.05). Where no transformation symbol exists in the table, no transformation was necessary. Untransformed data is presented, while levels of significance and coefficient of variation reflect analyses on transformed data. Visual assessments of crop injury were made in each trial. Positive taxonomic identification of *A. gossypii* and *C. dilutus* were made in each trial. The assessment methods used in these trials provided reliable data.

Table 1. Insecticides and formulation used in the trials.

Trade Name /Formulation	Active Ingredient	Concentration (g a.i./L or kg)
Transform™ Insecticide	Sulfoxaflor, XDE-208	240 SC
Regent®	Fipronil	200SC
Dimethoate 400	Dimethoate	400 EC
Pirimor® WG	Pirimicarb	500 WG
Assail® 700 WP	Acetamiprid	700 WP
Fulfill® 500	Pymetrozine	500 WG
Pegasus®	Diafenthiuron	500 SC
Pulse	Organosilicone	-
Maxx Organosilicone Surfactant™	Organosilicone	-
Hasten™ spray adjuvant	Esterified seed oil	-

Table 2. Trial details for *C. dilutus* trials.

Trial Number	104051RA	104008RA	104009RA	104010RA	114019RA
Year	2010	2010	2010	2010	2011
Author	D. Harvey	B. Griffith	B. Griffith	B. Griffith	N. Eulenstein
Location	NSW	NSW	NSW	NSW	NSW
Crop	*Gossypium hirsutum*	*Gossypium hirsutum*	*Gossypium hirsutum*	*Gossypium hirsutum*	Pigeon Pea
Variety	Sicot 80L	Sicot 71 BRF	Sicot 71 BRF	Sicot 71 BRF	N/R
Crop stage	Flowering	Flowering	Flowering	Flowering	Flowering
Mirid stage counted	Nymphs+ adults	Nymphs+ adults	Nymphs+ adults	Nymphs+ adults	Nymphs+ adults
Water rate (L/ha)	113	120	120	120	85
Pressure (kPa)	220	250	300	300	300
Nozzle type	Flat fan	Flat fan	Flat fan	Flat fan	Air induction
Nozzle Tip	XR 110011	XR110015VP	XR110015VP	XR110015VP	110-01

N/R = not recorded.

Table 3: Trial details for *A. gossypii* trials.

Trial Number	094005RA	104005RA	104004RA	Monsour2011
Year	2009	2009	2010	2011
Author	R. Annetts	C. Monsour	R. Annetts	C. Monsour
Location	Queensland	Queensland	Queensland	Queensland
Crop	*Gossypium hirsutum*	*Gossypium hirsutum*	*Gossypium hirsutum*	*Gossypium hirsutum*
Variety	Sicala 45	Sicot43RRF	Sicala 45	Sicot 43RRF
Crop Stage	Flowering	14-16 Nodes	Flowering	12-13 nodes
Aphid stage assessed	Wingless nymphs	Wingless nymphs	Wingless nymphs	Wingless nymphs
Water rate (L/ha)	100	100	100	100
Pressure (kPa)	300	270	300	276
Nozzle type	Hollow cone	Hollow cone	Hollow cone	Flat fan
Nozzle Tip	TX 6	TXVK-6	TX 6	XR TeeJet 110 02VS

Results and Discussion

This report describes nine trials carried out in the field in Australia. Five field trials investigated the efficacy of sulfoxaflor on *C. dilutus* in Australia (Table 4) and four trials investigating the efficacy of sulfoxaflor on *A. gossypii* (Table 5) in cotton. The 240 g/L suspension concentrate formulation of sulfoxaflor used in these trials was safe to all crops when applied as a foliar insecticide. Extensive field testing globally has demonstrated that all formulations of sulfoxaflor are safe to all crops when applied as a foliar insecticide according to label directions.

Table 4. Number of adult and nymph green mirids (per leaf) (5 trials).

Trial/Treatment		*DAA (date) Mean (±SE)*	*DAA (date) Mean (±SE)*	*DAA (date) Mean (±SE)*	*DAA (date) Mean (±SE)*	*DAA (date) Mean (±SE)*
104008RA g ai/ha		***1 (13-Jan-10)***	***3 (15-Jan-10) †***	***7 (19-Jan-10)***	***13 (25-Jan-10)***	
untreated		1.9 ±0.3 a	1.5 ±0.4 a	1.7 ±0.3 a	1.6 ±0.3 a	
sulfoxaflor	24	0.6 ±0.2 b	0.4 ±0.1 b	0.6 ±0.2 b	1.8 ±0.2 a	
sulfoxaflor	48	0.5 ±0.2 b	0.7 ±0.1 ab	0.4 ±0.1 b	1.0 ±0.2 a	
sulfoxaflor	72	0.7 ±0.2 b	0.1 ±0.1 b	0.6 ±0.2 b	1.3 ±0.4 a	
sulfoxaflor	96	0.8 ±0.3 b	0.5 ±0.1 b	0.2 ±0.0 b	1.6 ±0.3 a	
fipronil	12.5	1.0 ±0.3 ab	0.3 ±0.1 b	0.7 ±0.2 b	1.0 ±0.2 a	
fipronil	25	0.7 ±0.2 b	0.5 ±0.1 b	0.4 ±0.1 b	1.1 ±0.3 a	
CV		*49.23*	*50.18*	*60.5*	*43.57*	
114019RA		***1 (-Feb-11) †***	***3 (5-Feb-11)***	***7 (9-Feb-11)***	***13 (15-Feb-11)***	
untreated		4.2 ±0.8 a	3.1 ±0.5 a	2.1 ±0.1 a	2.1 ±0.4 a	
sulfoxaflor	24	1.2 ±0.3 b	0.4 ±0.2 b	1.0 ±0.1 b	2.9 ±0.7 a	
sulfoxaflor	48	1.1 ±0.2 b	0.4 ±0.2 b	0.8 ±0.1 b	2.3 ±0.5 a	
sulfoxaflor	72	0.9 ±0.1 b	0.8 ±0.3 b	1.5 ±0.2 ab	2.4 ±0.3 a	
sulfoxaflor	96	0.5 ±0.2 b	0 ±0 b	0.9 ±0.2 b	3.3 ±0.7 a	
fipronil	12.5	0.3 ±0.2 b	0.4 ±0.2 b	1.2 ±0.2 b	1.8 ±0.6 a	
fipronil	25	0.5 ±0.3 b	0 ±0 b	1.6 ±0.3 ab	2.3 ±0.3 a	
CV		*44.1*	*66.09*	*29.65*	*29.09*	
104010RA		***1 (22-Jan-10)***		***7 (28-Jan-10) †***	***14 (4-Feb-10) †***	
untreated		3.8 ±0.3 a		3.8 ±0.6 a	3.3 ±0.7 a	
sulfoxaflor	24	1.6 ±0.3 a		0.9 ±0.3 b	0.2 ±0.1 b	
sulfoxaflor	48	1.1 ±0.3 a		0.6 ±0.2 b	0.3 ±0.1 b	
sulfoxaflor	72	1.6 ±0.2 a		0.4 ±0.1 b	0.1 ±0.1 b	
sulfoxaflor	96	1.7 ±0.5 a		0.1 ±0.1 b	0.0 ±0.0 b	
fipronil	12.5	2.5 ±0.6 a		0.4 ±0.2 b	0.1 ±0.1 b	
fipronil	25	2.4 ±0.7 a		0.6 ±0.2 b	0.1 ±0.1 b	
CV		*55.59*		*49.04*	*55.72*	
104009RA			***3 (15-Jan-10)***	***6 (18-Jan-10) ‡***	***9 (21-Jan-10) †***	***21 (2-Feb-10) ‡***
untreated			2.8 ±0.3 a	1.7 ±0.2 a	1.5 ±0.7 a	0.2 ±0.03 a
sulfoxaflor	24		0.7 ±0.1 b	0.3 ±0.2 b	0.4 ±0.2 ab	0.1 ±0.03 a
sulfoxaflor	48		0.7 ±0.1 b	0.0 ±0.0 b	0.1 ±0.1 b	0.2 ±0.03 a
sulfoxaflor	72		0.2 ±0.1 b	0.1 ±0.1 b	0.1 ±0.1 b	0.2 ±0.03 a
sulfoxaflor	96		0.3 ±0.1 b	0.1 ±0.1 b	0.0 ±0.0 b	0.2 ±0.03 a
fipronil	12.5		0.7 ±0.3 b	0.0 ±0.0 b	0.1 ±0.1 b	0.2 ±0.03 a
fipronil	25		0.6 ±0.4 b	0.1 ±0.1 b	0.1 ±0.1 b	0.1 ±0.0 a
CV			*54.44*	*39.74*	*89.43*	*94.04*
104051RA			***3 (18-Jan-10)***	***6 (21-Jan-10)***	***12 (27-Jan-10)***	
untreated			1.5 ±0.2 a	0.7 ±0.1 a	0.8 ±0.2 ab	
sulfoxaflor	24		1.0 ±0.2 ab	0.3 ±0.0 ab	1.3 ±0.4 a	
sulfoxaflor	48		0.3 ±0.2 bc	0 ±0.0 b	0.8 ±0.2 ab	
sulfoxaflor	72		0.4 ±0.3 bc	0 ±0.0 b	0.3 ±0.2 ab	
sulfoxaflor	96		0.4 ±0.2 bc	0.1 ±0.1 b	0.3 ±0.2 ab	
fipronil	12.5		0.3 ±0.1 bc	0.1 ±0.1 b	0.3 ±0.3 ab	
fipronil	25		0 ±0 c	0.3 ±0.1 ab	0.1 ±0.1 b	
CV			*68.66*	*83.00*	*82.82*	

Means followed by same letter do not significantly differ (P=.05, Tukey's HSD)

† Log (x+1) transformation
‡ Arcsine square root percent(x) transformation
DAA= days after application
CV= coefficient of variation

Table 5. Number of wingless cotton aphids (per leaf) (4 trials)

Treatment	***Rate***	***DAA (date) Mean (±SE)***			***DAA (date) Mean (±SE)***			***DAA (date) Mean (±SE)***			***DAA (date) Mean (±SE)***			***DAA (date) Mean (±SE)***		
094005RA ai/ha	***g***	***4 (10-May-09) †***			***8 (14-May)-09†***			***15 (21-May-09)†***			***22 (28-May-09)***					
Untreated		8.6	±1.6	a	3.75	±0.7	a	1.9	±0.3	a	0.8	±0.1	a			
sulfoxaflor	24	0.2	±0.1	b	0.1	±0.1	b	0.1	±0.1	b	0.3	±0.1	b			
sulfoxaflor	48	0.2	±0.1	b	0.0	±0.0	b	0.0	±0.0	b	0.2	±0.1	b			
sulfoxaflor	72	0.1	±0.1	b	0.1	±0.1	b	0.0	±0.0	đ	0.0	±0.0	b			
acetamiprid♠	22.5	0.1	±0.1	b	0.1	±0.1	b	0.1	±0.1	b	0.1	±0.1	b			
pirimicarb	375	0.2	±0.2	b	0.0	±0.0	b	0.1	±0.1	b	0.1	±0.1	b			
CV		*39.85*			*55.15*			*59.65*			*58.51*					
104005RA		***3 (25-Jun-09)†***			***7 (29-Jun-09)†***			***14 (6-Jul-09)†***			***21 (13-Jul-09)†***			***28 (20-Jul-09)†***		
Untreated		19.4	±2.9	a	14	±2.8	a	19.2	±2.5	a	55.0	±1.9	a	62.2	±2.3	a
sulfoxaflor	24	0.6	±0.2	b	0.1	±0.1	b	0.1	±0.1	b	14.9	±2.1	b	21.3	±2.4	b
sulfoxaflor	48	0.4	±0.1	b	0.1	±0.0	b	0.1	±0.0	b	5.2	±1.1	b	6.8	±1.3	b
sulfoxaflor	72	0.2	±0.1	b	0.1	±0.0	b	0.2	±0.1	b	2.5	±0.7	b	3.1	±0.8	b
pymetrozine♠	200	0.8	±0.2	b	0.5	±0.2	b	0.2	±0.1	b	13.9	±1.7	b	19.3	±2.1	b
dimethoate	200	3.4	±0.9	b	2.0	±0.6	b	4.8	±1.0	b	26.8	±1.6	b	34.1	±1.8	b
CV		*49.98*			*96.22*			*48.59*			*13.78*			*9.86*		
104004RA		***2 (16-Apr-10)†***			***6 (20-Apr-10)‡***			***13 (27-Apr-10)***			***21 (5-May-10)***					
Untreated		15.08	±7.8	a	8.2	±2.7	a	1.43	±0.1	a	0.5	±0.1	a			
sulfoxaflor	24	1.08	±0.3	b	0.1	±0.1	b	0.0	±0.0	b	0.0	±0.0	b			
sulfoxaflor	48	0.9	±0.2	b	0.0	±0.0	b	0.0	±0.0	b	0.0	±0.0	b			
sulfoxaflor	72	0.48	±0.2	b	0.1	±0.1	b	0.0	±0.0	b	0.0	±0.0	b			
diafenthiuron	400	2.95	±0.8	b	0.5	±0.4	b	0.0	±0.0	b	0.1	±0.1	b			
pirimicarb	250	0.88	±0.3	b	0.9	±0.3	b	0.38	±0.3	b	0.1	±0.1	b			
CV		*43.6*			*60.36*			*78.49*			*136.7*					
monsour2011		***3 (5-Sep-11)†***			***7 (9-Sep-11)†***			***14 (16-Sep-11)†***			***21 (23-Sep-11)†***					
Untreated		16.2	±4.1	a	20.1	±5.5	a	41.7	±9.4	a	38.9	±8.0	a			
sulfoxaflor	24	0.6	±0.2	a	2.1	±0.6	a	5.2	±1.5	a	10.2	±1.4	a			
sulfoxaflor	48	1.2	±0.7	a	0.3	±0.2	a	3.1	±1.3	a	8.0	±4.1	a			
sulfoxaflor	72	4.5	±2.1	a	0.8	±0.6	a	2.2	±0.5	a	4.1	±0.7	a			
spirotetramat♥	72	2.2	±0.8	a	3.9	±2.1	a	5.9	±1.4	a	9.1	±1.4	a			
clothianadin♣	50	4.0	±0.8	a	2.7	±1.9	a	7.6	±2.9	a	10.3	±1.5	a			
diafenthiuron	400	6.0	±1.5	a	1.1	±0.3	a	3.7	±0.8	a	4.8	±1.0	a			
pirimicarb	375	8.3	±1.3	a	8.0	±2.9	a	26.4	±6.4	a	26.1	±5.0	a			
dimethoate	100	6.3	±2.1	a	3.7	±1.5	a	24.1	±3.6	a	23.9	±3.6	a			
CV		*92.34*			*113.13*			*66.93*			*45.51*					

Means followed by same letter do not significantly differ (P=.05, Tukey's HSD)
♠Plus Pulse 0.2% v/v
♣plus Maxx 0.2 % v/v
♥ plus Hasten 1 L/ha
† Log (x+1) transformation
‡ Arcsine square root percent(x) transformation
DAA= days after application
CV= coefficient of variation

C. dilutus

C. dilutus is a difficult pest to assess as it is highly mobile and moves around the crop quickly making counting difficult. *C. dilutus* is also an extremely damaging pest with low numbers causing economic damage quickly. All trials assessed both adults and nymphs and are presented as adults and nymphs per meter of crop row. All trials were completed on large populations of *C. dilutus.* Sulfoxaflor gave quick knock down of *C. dilutus* 1-3 days after application and was significantly superior to the untreated in all but one trial (104010RA), although sulfoxaflor was numerically superior to the untreated in this trial. These data show that sulfoxaflor at 48-72 g ai/ha was needed to give reliable and robust control of *C. dilutus* equivalent to the standard fipronil at the rates tested across the trials.

A. gossypii

All trials were completed on large populations of *A. gossypii.* Sulfoxaflor at all rates (24, 48 & 72 g ai/ha) gave very good control of *A. gossypii* and gave significantly better control compared to the untreated control in all except one trial (Monsour2011), which is discussed below. All rates of sulfoxaflor gave very good knock down 2 to 4 days after application, although these data show that sulfoxaflor rates of 48 to 72 g ai/ha were needed for more reliable control. Sulfoxaflor at 48 to 72 g ai/ha gave residual control of *A. gossypii* 21-28 days after application and was equivalent or superior to the standards. In two trials, dimethoate showed slightly less control, which may indicate resistance of *A. gossypii* to organophosphate insecticides. One trial (104005RA) demonstrated 21 to 28 day residual control of *A. gossypii* at rates from 48 to 72 g ai/ha, which was clearly numerically superior to that given by the standards. In one trial, (Monsour2011) there were no significant treatment differences for the control of *A. gossypii* at any assessment, however, there were dramatic numerical differences between the untreated control and all of the insecticide treatments at all assessment dates. Interestingly, statistical analysis on untransformed data yielded significant differences between the untreated and treated plots; however, due to the variability of the data, transformation was necessary and any significant difference disappeared after transformation. This trial showed that (at least numerically) sulfoxaflor was equivalent to (diafenthiuron, clothianidin and spirotetramat) or superior to (pirimicarb and dimethoate) most standards.

Summary

Control of both *C. dilutus* and *A. gossypii* is currently predominantly achieved through use of insecticides. There are few insecticides registered for use on *C. dilutus* in Australia and these include pyrethroids, fipronil, neonicotinoids, and indoxacarb. There is no known insecticide resistance in *C. dilutus* in Australia, although there is currently no resistance monitoring program. It is possible that resistance to insecticides could develop if a proactive approach to preventing resistance is not taken. Resistance in aphids to the most commonly used insecticides in Australia and around the globe, i.e. neonicotinoids, carbamates, synthetic pyrethroids and organophosphates, is well documented (Wilson *et al.,* 2008). Aphids are well suited to the development of resistance as they reproduce asexually. This means that all the progeny of a resistant individual will be resistant, and once resistance is selected in a population it can quickly dominate. Studies carried out by Dow AgroSciences have demonstrated no cross-resistance to sulfoxaflor in populations of insects resistant to any other chemical class (Zhu *et al.,* 2011; Babcock *et al.,* 2010). Sulfoxaflor represents a valuable new mode of action for the prevention (when used in rotation with other insecticide MOAs) and management of resistant populations of sap feeding insects.

Integrated pest management (IPM), where all crop protection methods are considered in a broad suite of tools, rather than sole reliance on insecticides is entrenched in Australian cotton production. Many of the insecticides currently used for control of *C. dilutus* and *A. gossypii* are disruptive to beneficial predators and parasitoids, especially early season use of dimethoate and pyrethroids. The beneficial insect profile of sulfoxaflor has been studied in Australia. Trial results (unpublished, Wilson and Heimoana, 2011) show that sulfoxaflor has a favorable beneficial profile, although increasing rates had an increasing negative effect; sulfoxaflor tested at the highest proposed field rate at of 96 g ai/ha had a very low effect on spiders, a low effect on wasps and predatory beetles, a moderate effect on predatory bugs and Trichogrammatids and a high effect on thrips, ants, apple dimpling bugs and lacewings. The effect of sulfoxaflor on beneficial insects was reduced as the rate of sulfoxaflor was reduced, with sulfoxaflor at the lowest tested (24 g ai/ha) having a very low effect on spiders, a low effect on wasps, predatory beetles, lacewings and ants a moderate effect on thrips, predatory bugs and Trichogrammatids and a high effect on apple dimpling bugs. The introduction of insecticides such as sulfoxaflor which are relatively safe to beneficial insects will facilitate the continued adoption of IPM in Australian cotton.

Cotton Bunchy Top syndrome, a viral disease spread by cotton aphids, is currently the greatest threat to high yielding cotton production in Australia. Cultural control methods and insecticide applications are currently the only methods of managing Cotton Bunchy Top syndrome. Research is underway to breed new cotton varieties that are resistant to the disease but these are years away from commercialization. Trial work carried out by Dow AgroSciences (unpublished data) has demonstrated a reduction in the transmission of plant viruses through applications of sulfoxaflor to virus-vectoring aphids. Work is continuing on the interactions between sulfoxaflor and Cotton Bunchy Top syndrome, and it is expected that sulfoxaflor will be a valuable tool for Australian cotton growers.

Sulfoxaflor has an excellent fit in IPM programs because of its spectrum of activity and low impact on many key beneficial insects. It has low mammalian toxicity, and has minimal effect on non-target organisms such as fish, birds, and aquatic invertebrates. Sulfoxaflor will provide cotton growers with robust control of *C. liebknechti* and *A. gossypii*. With its novel mode of action, sulfoxaflor will be a useful rotational partner with existing insecticides and help delay the development of insecticide resistance. Sulfoxaflor will have a broad label in broadacre and horticulture and will be registered for control of all major species of sap-feeding pests in Australia.

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