BLUE ALFALFA APHID: OLD PEST WITH NEW MANAGEMENT CHALLENGES

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ABSTRACT

Blue alfalfa aphid has been a serious pest of alfalfa in the western United States for the past 40 years but has been successfully managed by implementing IPM practices; most notably, host plant resistance, economic treatment thresholds and insecticides. However, since the spring of 2013, blue alfalfa aphid is once again causing severe economic losses to alfalfa growers in California and throughout the Desert Southwest. Several reasons for the recent outbreaks have been proposed including: a new strain of blue alfalfa aphid that broke host plant resistance, development of insecticide-resistance, depletion of aphid natural enemies (e.g. predator and parasite) caused by increased use of broad spectrum insecticides, and regional changes in climate, for example, a 46% decrease in winter fog events in the Central Valley, with warmer weather favoring pest development.

Key Words: blue alfalfa aphid, insecticide-resistance, host plant resistance, natural enemies

INTRODUCTION
A History of Aphid Outbreaks and Management

The western United States has a long history of alfalfa aphid outbreaks but also a history of meeting the challenges of finding solutions to devastating aphid outbreaks through research and implementation of integrated pest management (IPM) practices including breeding of aphid-resistant alfalfa varieties. Sixty years ago, in 1954, spotted alfalfa aphid *Therioaphis maculatato* (Buckton), (SAA) became the first and most devastating alfalfa aphid outbreak, destroying millions of acres of alfalfa in the United States. SAA was first documented in New Mexico in 1953 and by 1954 had spread westward into California (Tuttle and Butler, 1954). The development of lasting SAA-resistant alfalfa was a long and tedious effort involving overcoming host plant resistance breaking SAA biotypes. Eventually six SAA biotypes segregated on their ability to overcome host plant resistant alfalfa line to were identified (Nielson et al. 1970) and host plant resistance to all six SAA biotypes led to release of several alfalfa varieties with SAA-resistance. In addition to host plant resistance breaking biotypes, several insecticide-resistant SAA biotypes have been identified (Stern and Reynolds, 1958; Nielson and Don 1974).

During the late-1980's, Imperial Valley pest control advisers (PCAs) began reporting black aphids on seedling alfalfa in October but the aphids were not causing harm to established stands

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of alfalfa. The black aphid was identified as cowpea aphid, *Aphis craccivora* Koch, (CPA) (Natwick 1991). However, by the winter of 1998 and spring of 1999, CPA was causing serious injury to established alfalfa in Imperial County, CA and moving northward (Natwick 1999a, 1999b and 1999c; Summers 2000a and 2000b). CPA continued to move northward and eastward and now is a pest of alfalfa across the United States (Berberet et al. 2009). This aphid continues to be a serious pest of low desert alfalfa hay production and has been mostly managed with use of insecticides. Host plant resistance studies were initiated by Larry Teuber (UC Davis), but no highly CPA-resistant alfalfa varieties were released prior to his passing in 2014. In the Middle East, CPA is a vector of a serious alfalfa disease causing agent, *Alfalfa enation virus* (AEV); fortunately, it is not found in North America.

Imperial County, CA alfalfa growers reported less than adequate control of pea aphid *Acyrthosiphon pisum* (Harris), PA using insecticides during the spring of 1975 (Sharma et al. 1976). An investigation was undertaken and it was determined that a new aphid pest, blue alfalfa aphid, Acyrthosiphon kondoi Shinji, (BAA) was established in California alfalfa fields. An earlier sweep net sample of alfalfa insects collected near Bakersfield, CA for detection of lygus bug parasites in 1974 was stored in EtOH and used to the document the earliest find of BAA in California. The two aphid species, PA and BAA, are similar in size and color and often occur in mixed populations. They are easily confused one for the other without closer examination using a 10X hand lens. Looking at the aphid’s antennae with a hand lens the two species can easily be distinguished; BAA had uniformly dark antennae and PA has lighter colored antennae with dark bands around the antennal joints.

The new aphid, BAA spread quickly across the United States, particularly in the warmer regions (Nielson and Kodet 1975; Nielson et al. 1976a). Sharma et al. 1975, reported that BAA was easily killed by low rates of a wide range of insecticides, but re-infestation was reported to be extremely rapid. Alfalfa plant breeders and entomologists were able draw on past experience from previous outbreaks of alfalfa aphid pests such as the SAA to research and implement IPM practices to manage the new aphid pest. These IPM practices included development of BAA-resistant alfalfa varieties such as CUF 101 (Nielson et al. 1976b; Lehman et al. 1978), development of an economic threshold level for BAA (Sharma and Stern 1980), and identifying the most efficacious and least disruptive chemical control measures when needed. . For many years, BAA was well managed in alfalfa fields across California using these IPM approaches.

However, BAA re-emerged as the most serious alfalfa aphid pest during the spring of 2013 in Imperial, Kern and Merced Counties, reaching Klamath Basin in spring 2014 (Barlow and Natwick 2013, Orloff pers. comm.) and has moved eastward and northward reaching southern Utah by the summer of 2014 (Ramirez 2014). The current problems with BAA are dynamic as the problem expands into alfalfa stands across the United States, the cause of the problem is still unexplained and solutions to the problem remain elusive. Although alfalfa IPM practices have served growers well for management of BAA for nearly 40 years, we are now facing new challenges trying to manage this pest. The question yet to be adequately answered is: “What has changed that is now allowing BAA to cause widespread damage to western alfalfa?” Several reasons for the recent outbreaks have been proposed including a host plant resistance breaking strain of BAA (Humphrie et al. 2012). Host plant resistance to aphid pests is a key component of IPM in alfalfa, including the BAA. Insecticides depletion of aphid natural enemies (e.g. predator and parasite) has also been suggested as a cause of BAA outbreaks. It was correctly stated (Godfrey et al., 2013) that for many years, alfalfa has been a model system for the development, implementation, and use of IPM tactics in California. IPM programs in the southwestern United States and throughout California depend on alfalfa as a source of natural enemies that help keep pest insects in check in a diverse array of crops including cotton, grain crops, sugarbeet and vegetable crops.

BAA INSECTICIDE EFFICACY TRIAL

Several insecticides registered or under development for aphid management were evaluated by Eric Natwick during the winter-spring alfalfa seasons of 2013 (Table 1; 4-experiments) and 2014 (Table 2; 2-experiments). Plots measured 13.3 ft by 50 ft. Broadcast spray applications were made with a Lee Spider Spray Trac, tractor mounted spray boom, operated at 30 psi, delivering 53 gpa through 12 nozzles (TJ-60 11003VS) with a 13.3 ft spray swath. Data sets were analyzed using a 2-way ANOVA and means separated by Fisher protected LSD ($P \leq 0.05$). Following the first insecticide experiment treatments applied on January 17, 2013, BAA was very well controlled as evidenced by the rapid knockdown, long residual activity and the control percentages based on the post-treatment averages (PTA). The percentages of control, knockdown and residual activity were still good following the February 22, 2013 series of insecticide application to alfalfa for BAA control; although somewhat diminished compared to the January insecticide applications. The February 28, 2013 insecticide treatments still showed good knockdown and residual activity but even lower control percentages than the two earlier insecticide efficacy evaluations for BAA control in 2013. Following the April 5, 2013 insecticide applications to alfalfa for BAA control, it was evident that all of the insecticide had diminished BAA knockdown activity and some insecticides had very poor control percentages. It is difficult to access the residual control because the onset of hot weather in mid-April caused the overall BAA levels to crash regardless of insecticide treatment or untreated control. In both of the BAA insecticide efficacy experiments in 2014 applied on February 5 and February 7, respectively, there was poor knockdown activity, poor residual activity and only fair to poor control percentages (Table 2). Some of the newer chemistries such as Sivanto 200SL, Transform 50WG, Beleaf 50SG and Cyclaniliprole 50SL provided the best control percentages following the February 5, 2014 treatment applications. Following the February 7, 2014 insecticide treatment applications, knockdown was poor, residual activity was poor and percentages of control were poor; Beleaf 50SG provided the highest level of control at 66.0 percent. Only Beleaf has a 24C special local needs label for use in California and none of the other new insecticides are registered for use in alfalfa hay production in California at the time of publication of this report.

The percentages of control for various chemistries against BAA from 2009 through March 2014 are shown in Table 3. It is evident that the control percentages began to drop for organophosphate insecticides, pyrethroid insecticides and combinations of the two chemistries late in the spring of 2013 and continued to be low in the spring of 2014. With the newer chemistries of flupyradifurone (Sivanto 200SL), sulfoxaflor (Transform 50WG) and flonicamid (Beleaf 50SG) the drop in control percentages was not nearly as dramatic. This drop-off of control percentages is shown graphically in Figures 1-4 for organophosphates, for pyrethroids, for nicotinic acetylcholine agonist (nAChR) insecticides (Sivanto and Transform), and for flonicamid (Beleaf 50SG), respectively. What appears to be evident for the six insecticides efficacy studies in 2013 and 2014 along with comparisons as far back as 2004, is that there began to be a problem with control of BAA in the Imperial Valley, CA in the late spring of 2013 continuing through the spring of 2014. This correlates with the reports from numerous PCAs in the low desert alfalfa production valleys of Arizona and southeastern California, as well as San Joaquin Valley. Numerous reports of high levels of BAA and control difficulties have been reported throughout California and the western United States as far north as southern Utah by the summer of 2014. What is not confirmed from the insecticide efficacy studies is insecticide-resistance, but it is certainly suggested. It also remains unclear if there is a host plant resistance breaking strain of BAA that has developed or been introduced into the western United States.

For many years, alfalfa producers have placed a high reliance on just a few active ingredients. Although quick and dirty bioassays of key AIs have been conducted, the question of resistance to these key modes of action represented primarily by IRAC categories organophosphates (1B) and pyrethroids (3A). There is an urgent need for registration of additional active ingredients such as those demonstrated from these field trials to manage aphid pests as well products from the older neonicanoid group (4A).

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Table 1. Blue alfalfa aphid management with insecticides, Winter-Spring 2013.

Blue Alfalfa Aphids per Sweep, Holtville, CA, applied January 17, 2013

Treatment	oz/ac	1DPT^{w}	5DAT^{x}	8DAT	11DAT^{y}	14DAT^{y}	PTA^{yz}	PTA % control
Check	-----	0.40 a	0.50 a	1.98 a	11.65 a	14.38 a	7.13 a	----------
Sivanto 200SL	10.5	3.90 a	0.08 a	0.20 c	0.43 cd	0.63 b-d	0.33 b-e	95.4
Transform 50WG	1.5	1.73 a	0.05 a	0.68 b	4.30 bc	1.03 b	1.51 b	78.8
Dimethoate 2.67EC	16	7.73 a	0.05 a	0.08 c-e	0.98 b-d	0.43 b-d	0.38 b-e	94.7
Malathion 8	16	1.20 a	0.05 a	0.25 cd	0.58 b-d	2.45 bc	0.83 b-d	88.4
Beleaf 50 SG	2.24	0.00 a	0.13 a	0.23 cd	1.68 b	0.70 bc	0.68 bc	90.5
Mustang 1.5E	4.3	0.65 a	0.03 a	0.03 de	0.30 d	0.13 cd	0.12 de	98.3
Stallion 2.5EW	11.75	3.18 a	0.18 a	0.00 e	0.48 cd	0.15 cd	0.20 de	97.2
Lorsban Advanced	32	1.43 a	0.10 a	0.10 c-e	0.18 d	0.15 cd	0.13 de	98.2
Cobalt 2.54 EC	24	1.45 a	0.18 a	0.03 de	0.10 d	0.00 d	0.08 e	98.9
Centric 40 WG	3.5	0.38 a	0.00 a	0.08 c-e	0.18 d	0.08 cd	0.08 de	98.9
Warrior II 2.08CS	1.92	0.75 a	0.03 a	0.10 c-e	0.08 d	0.83 bc	0.23 c-e	96.8
Endigo ZC 2.06SE	4.0	0.05 a	0.13 a	0.13 c-e	0.08 d	0.05 cd	0.09 de	98.7

Blue Alfalfa Aphids per Sweep, Holtville, CA, applied February 22, 2013.

Treatment	oz/ac	1 DPT^{w}	3 DAT^{xz}	7 DAT	10 DAT	14 DAT	PTA^{yz}	PTA % control
Check	------	105.05 a	58.58 a	38.83 a	82.50 a	39.10 b	54.75	------------
Warrior II	1.92	127.80 a	10.95 bc	8.63 c	15.55 b	24.23 bc	14.84 b	72.9
Endigo ZCX	4.0	84.00 a	1.08 f	3.05 c	4.48 b	13.73 c	5.58 bc	89.8
Besiege	9.0	103.05 a	5.55 cd	2.93 c	16.63 b	21.60 bc	11.68 b	78.7
Cobalt Advanced	24.0	69.75 a	2.23 de	1.60 c	5.73 b	6.60 c	4.11 c	92.5
Mustang	4.3	91.48 a	4.53 d	3.20 c	13.13 b	18.13 bc	9.74 b	82.2
Stallion 3.025EC	9.25	95.98 a	3.53 d	2.38 c	14.33 b	13.45 c	8.42 bc	84.6
Stallion 3.025EC	11.75	105.05 a	2.08 ef	2.25 c	5.48 b	22.45 bc	8.06 bc	85.3
Danitol	16.0	115.23 a	13.98 b	22.28 b	65.45 a	65.45 a	41.79 a	23.7

Blue Alfalfa Aphids per Sweeps, Holtville, CA, applied February 28, 2013.

Treatment	oz/ac	PT^{w}	3 DAT^{x}	7 DAT^{z}	14 DAT	PTA^{yz}	% control from PTA
Check	--------	58.48 a	65.66 a	82.64 a	86.36 a	78.22 a	-------------
Paradigm VC	3.84	60.02 a	17.12 b	18.68 b	20.16 b	18.65 b	76.2
Baythroid XL	1.9	49.58 a	11.84 b	23.20 b	26.12 b	20.39 b	73.9
Mustang	4.3	54.44 a	11.42 b	15.40 b	23.00 b	16.61 b	78.8
Lorsban Advanced	24.0	81.56 a	8.20 b	7.28 c	15.34 b	10.27 c	86.9
Warrior II	1.92	72.64 a	14.58 b	6.94 c	15.92 b	12.48 bc	84.0

Blue Alfalfa Aphids per Sweep, Holtville, CA, applied 5 April 2013.

Treatment	Rate oz/ac	1 DPT[w]	3 DAT[xz]	7 DAT	10 DAT	14 DAT	PTA[yz]	PTA % control
Check	------	4.75 a	2.23 a	8.15 a	0.75 c	0.23 a	2.84 a	-------------
Sivanto 200SL	10.5	3.88 a	0.58 a	1.38 cd	0.33 c	0.00 c	0.57 d	79.9
Transform WG	1.5	7.48 a	0.05 a	0.73 d	0.08 c	0.00 c	0.21 d	92.6
Dimethoate 2.67EC	16	5.33 a	0.30 a	2.38 bcd	0.08 c	0.00 c	0.69 cd	75.7
Malathion 8	16	3.10 a	3.10 a	4.70 a-d	0.18 c	0.00 c	1.99 abc	29.9
Beleaf 50 SG	2.24	7.35 a	1.75 a	2.43 bcd	0.13 c	0.00 c	1.08 bcd	62.0
Mustang	4.3	5.20 a	1.80 a	5.85 ab	1.60 bc	0.15 b	2.35 ab	17.3
Stallion	11.75	5.70 a	1.50 a	6.18 ab	3.58 a	0.00 c	2.81 a	1.1
Lorsban Advanced	32	2.95 a	2.48 a	4.83 abc	0.85 c	0.00 c	2.04 ab	28.2
Cobalt Advanced	24	2.55 a	1.50 a	4.98 abc	2.63 ab	0.00 c	2.28 ab	19.7
Centric 40 WG	3.5	4.43 a	1.45 a	2.55 bcd	1.50 c	0.00 c	1.03 bcd	63.7
Warrior II CS	1.92	4.20 a	0.60 a	1.40 cd	0.00 c	0.00 c	0.50 d	82.4
Endigo ZC	4.0	4.93 a	0.53 a	1.68 cd	0.40 c	0.03 c	0.66 d	76.8

Means within columns followed by the same letter are not significantly different, LSD; *P*= 0.05.

[w] Pre-treatment [x] Days after treatment [y] Post treatment average.

[z] Log_{10} (X+1) transformed data used for analysis, actual means reported

Table 2. Blue alfalfa aphid management with insecticides, Spring 2014.

Blue Alfalfa Aphids per Sweep, Holtville, CA, applied 5 February 2014.

Treatment/ formulation	oz/ac	1DPT[w]	5 DAT[x]	7 DAT	14 DAT	21 DAT	PTA[y]	PTA % control
Check	------	672.75 a	814.25 a	879.75 a	1604.00 a	705.00 ab	1000.75 a	---------
Cobalt Advanced	26.0	758.00 a	54.25 c	253.75 cd	988.00 abc	653.50 ab	487.38 bcd	51.3
Lorsban Advanced	26.0	687.50 a	182.00 bc	510.25 abc	559.25 bc	901.25 a	538.19 bcd	46.2
Transform WG	0.75	669.25 a	128.25 bc	252.25 cd	287.25 bc	391.50 ab	264.81 d	73.5
Transform WG	1.50	718.50 a	78.75 bc	35.75 d	341.00 bc	214.25 b	167.44 d	83.3
Sivanto 200SL	7.0	821.75 a	111.50 bc	191.25 cd	432.50 bc	296.00 ab	257.81 d	74.2
Sivanto 200SL	10.0	913.75 a	40.25 c	133.00 d	407.25 bc	372.50 ab	238.25 d	76.2
Cyclaniliprole 50SL	16.4	745.25 a	441.50 ab	770.75 ab	1086.25 abc	782.25 ab	770.19 abc	23.0
Cyclaniliprole 50SL	20.0	638.50 a	683.25 a	956.75 a	1293.25 ab	583.00 ab	879.06 ab	12.2
Cyclaniliprole 50SL + Beleaf 50SG	10.9 1.71	656.50 a	166.75 bc	192.75 cd	278.75 c	292.50 ab	232.69 d	76.74
Assail 30SG	3.0	546.50 a	176.00 bc	347.75 bcd	544.50 bc	294.25 ab	340.63 cd	66.0
Assail 30SG	5.0	771.50 a	140.75 bc	223.00 cd	150.00 c	347.00 ab	215.19 d	78.5
Assail 30SG	7.0	1050.00 a	100.25 bc	285.00 cd	794.00 abc	510.00 ab	422.31 cd	57.8

Blue Alfalfa Aphids per Sweep, Holtville, CA, applied 7 February 2014.

Treatment/ formulation	Rate oz/ac	3-DPT[w]	3-DAT[x]	7-DAT	14-DAT[z]	21-DAT	PTA[y]	PTA % control
Untreated check	------	50.75 a	159.38 a	98.85 a	71.35 a	51.80 ab	97.31 a	---------
Warrior II	1.92	44.53 a	34.03 c	30.73 b	13.93 c	52.43 ab	47.46 bc	51.2
Endigo ZCX	3.9	42.48 a	21.55 c	26.28 b	23.34 bc	37.03 ab	39.91 bc	59.0
Besiege 1.25ZC	9.0	43.93 a	39.45 bc	34.68 b	32.48 abc	54.15 ab	52.44 bc	46.1
Cobalt Advanced	24.0	35.38 a	27.30 c	28.33 b	28.02 abc	41.63 ab	49.97 bc	48.6
Fulfill 50WDG	5.5	40.53 a	78.20 bc	61.08 ab	54.35 ab	39.68 ab	58.93 abc	39.4
Grandevo DF2	48.0	39.63 a	98.88 ab	69.05 ab	61.70 ab	88.08 a	81.11 ab	16.6
Beleaf 50SG	2.8	42.90 a	51.78 bc	32.60 b	29.01 abc	17.80 b	36.98 c	62.0
Mustang 1.5EW	4.3	44.35 a	42.28 bc	44.25 ab	38.54 ab	41.95 ab	53.17 bc	45.4
Stallion 3.025EC	11.75	38.05 a	28.58 c	24.73 b	23.83 bc	51.70 ab	49.07 bc	49.6
Stallion 3.025EC+ Dimethoate 2.67E	11.75 16.0	57.53 a	23.25 c	27.18 b	25.13 bc	35.73 ab	41.29 bc	57.6

Means within columns followed by the same letter are not significantly different, LSD; *P*= 0.05.

[w] Pre-treatment [x] Days after treatment [y] Post treatment average.

[z] Log_{10} (X+1) transformed data used for analysis, actual means reported

Table 3. Blue alfalfa aphid control percentages form post-treatment averages

IRAC #	Insecticide	lb ai/ac	2009	2010	2011	2012	2013a	2013b	2013c	2013d	2014a	2014b
1B OPs	Malathion	1.0	-----	-----	-----	97.1	88.4	-----	-----	29.9	-----	-----
	Dimethoate	0.33	-----	84.9	-----	81.9	94.7	-----	-----	-----	-----	-----
	Chlorpyrifos	0.125	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
		0.47	98.1	-----	-----	-----	-----	-----	-----	-----	-----	-----
		1.0	-----	83.2	-----	-----	98.2	-----	86.9	28.2	46.2	-----
3A pyrethroids	Lambda-cyhalothrin	0.015	-----	-----	-----	-----	97.2	72.9	84.0	82.4	-----	51.2
		0.025	-----	90.9	-----	-----	-----	-----	-----	-----	-----	-----
		0.027	-----	-----	-----	-----	-----	-----	76.2	-----	-----	-----
	Zeta-cypermethrin	0.025	-----	85.7	-----	-----	-----	-----		-----	-----	-----
		0.05	-----	-----	97.3	-----	98.3	82.2	78.8	17.25	-----	45.4
	Gamma-cyhalothrin	0.021	-----	-----	-----	-----	-----	-----		-----	-----	-----
	Cyfluthrin	0.0413	-----	-----	-----	-----	-----	-----	73.9	-----	-----	-----
	Fenpropathrin		-----	-----	91.0	-----	-----	23.7	-----	-----	-----	-----
4D Butenolides	Flupyradifurone (Sivanto 200SL)	0.137	-----	-----	-----	86.7	95.3	-----	-----	79.9	74.2	-----
		0.183	-----	-----	-----	87.6	-----	-----	-----	-----	76.2	-----
4C sulfoximines	Sulfoxaflor (Transform 50WG)	0.047	-----	-----	-----	90.5	-----	-----	-----	-----	73.5	-----
		0.055	-----	-----	-----	85.7	78.8	-----	-----	92.6	83.3	-----
9C pyridincar-boxamids	Flonicomid (Beleaf 50SG)	0.07	-----	-----	-----	89.5	-----	-----	-----	62.0	76.7	62.0
3A + 4A	Lambda-Cyhalothrin + Thiamethoxam	0.037 0.028	-----	-----	99.3	-----	98.7	89.8	-----	76.8	-----	59.0
1B + 3A	Chlorpyrifos + Gamma-Cyhalothrin	0.625 0.0113	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
		0.51 0.009	97.2	-----	-----	-----	98.9	92.5	-----	19.7	51.3	48.6
		0.371 0.0067	98.4	-----	-----	-----	-----	-----	-----	-----	-----	-----
	Chlorpyrifos + Zeta-Cypermethrin+	0.25 0.025	-----	86.8	99.2	-----	97.2	85.3	-----	1.1	-----	49.6
	Chlorpyrifos + lambda-Cyhalothrin	0.47 0.024	-----	-----	99.2	-----	-----	-----	-----	-----	-----	-----

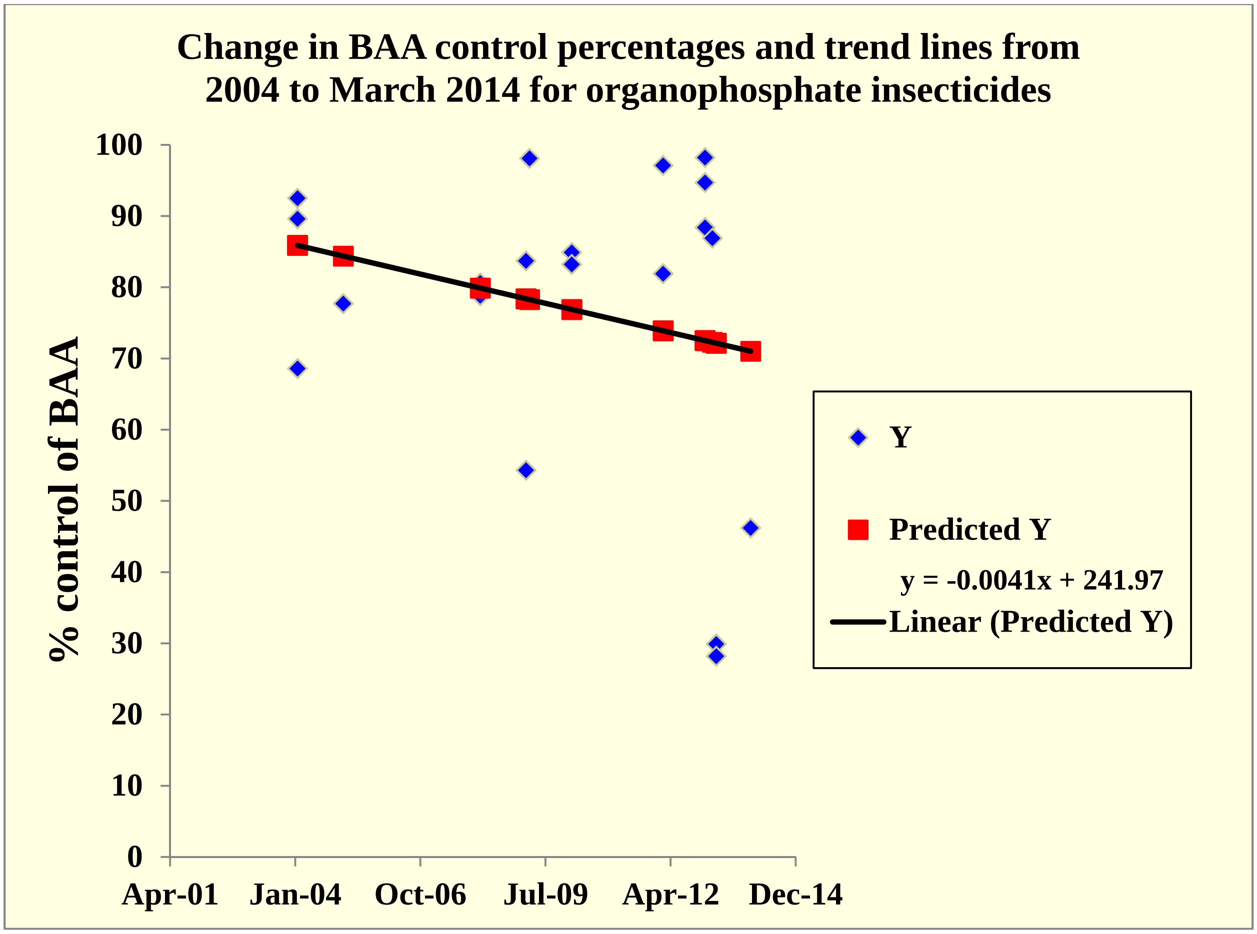

Figure 1. BAA control percentages and trend lines from 2004 to March 2014 for organophosphate insecticides (chlorpyrifos, dimethoate and malathion); IRAC# 1B.

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	497.9904	497.9904	1.111985	0.305601
Residual	18	8061.107	447.8393		
Total	19	8559.098			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	241.9746	156.3528	1.547619	0.139116	-86.5105	570.4597	-86.5105	570.4597
X Variable 1	-0.00411	0.003893	-1.05451	0.305601	-0.01229	0.004074	-0.01229	0.004074

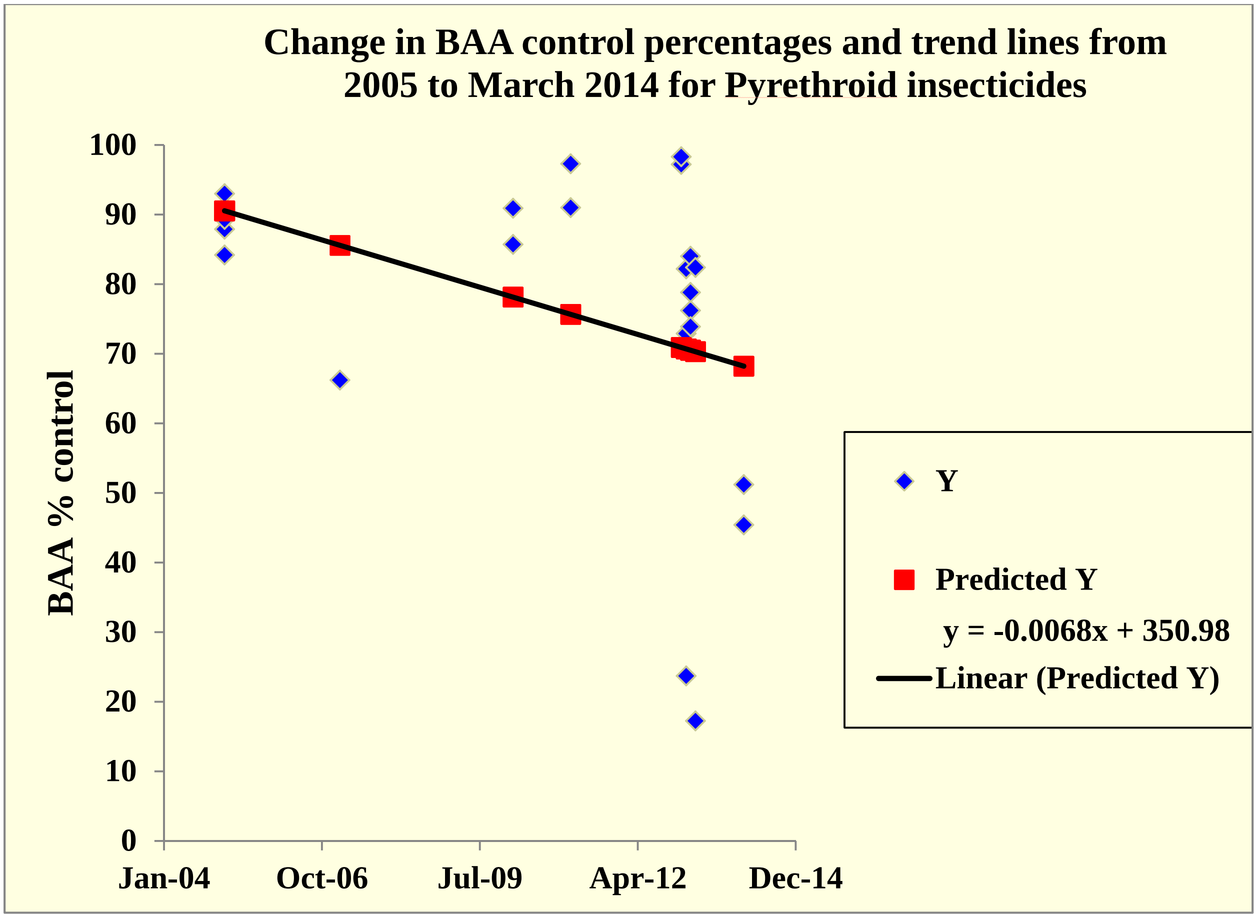

Figure 2. BAA control percentages and trend lines from 2005 to April 2014 for pyrethroid insecticides (bifenthrin, cyfluthrin, fenpropathrin, gama-cyhalothrin, lambda-cyhalothrin and zeta-cypermethrin); IRAC # 3A.

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1593.77	1593.77	3.634992	0.070353
Residual	21	9207.498	438.4523		
Total	22	10801.27			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	350.9832	144.0507	2.436526	0.023817	51.41347	650.553	51.41347	650.553
X Variable 1	-0.00679	0.003559	-1.90657	0.070353	-0.01419	0.000616	-0.01419	0.000616

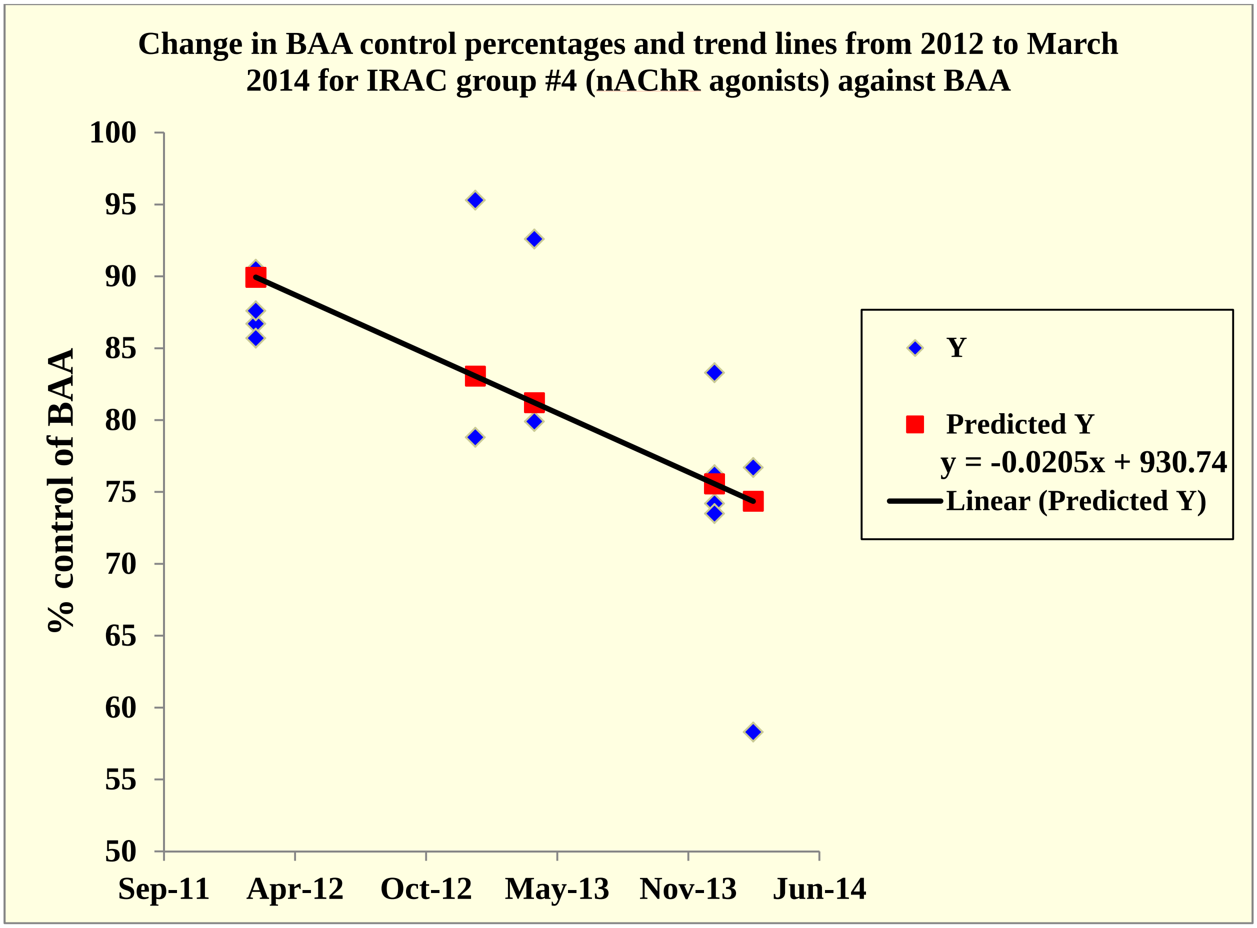

Figure 3. BAA control percentages and trend lines from 2012 to April 2014 for two nicotinic acetylcholine agonist (nAChR) insecticides; sulfoxaflor (Transform WG) and flupyradifurone (Sivanto 200SL) IRAC #'s 4C and 4D, respectively.

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	532.8823	532.8823	9.642001	0.009102
Residual	12	663.2013	55.26677		
Total	13	1196.084			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	930.7379	273.5391	3.402578	0.005245	334.7475	1526.728	334.7475	1526.728
X Variable 1	-0.02054	0.006614	-3.10516	0.009102	-0.03495	-0.00613	-0.03495	-0.00613

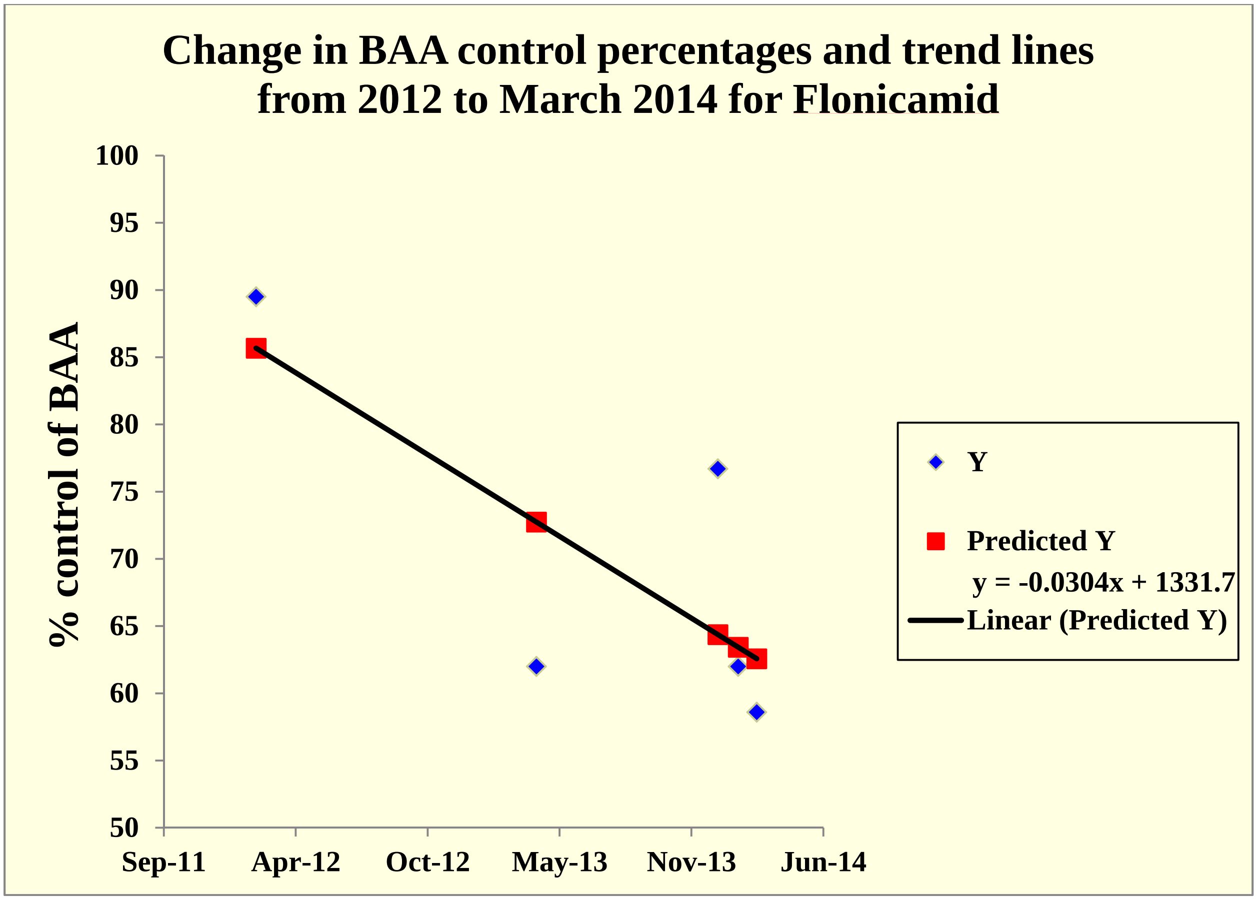

Figure 4. BAA control percentages and trend lines from 2012 to March 2014 for Flonicamid (Beleaf); IRAC # 9C.

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	382.9789	382.9789	3.83192	0.145202
Residual	3	299.8331	99.94438		
Total	4	682.812			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1331.737	644.6939	2.065688	0.130781	-719.967	3383.44	-719.967	3383.44
X Variable 1	-0.03044	0.015548	-1.95753	0.145202	-0.07992	0.019045	-0.07992	0.019045

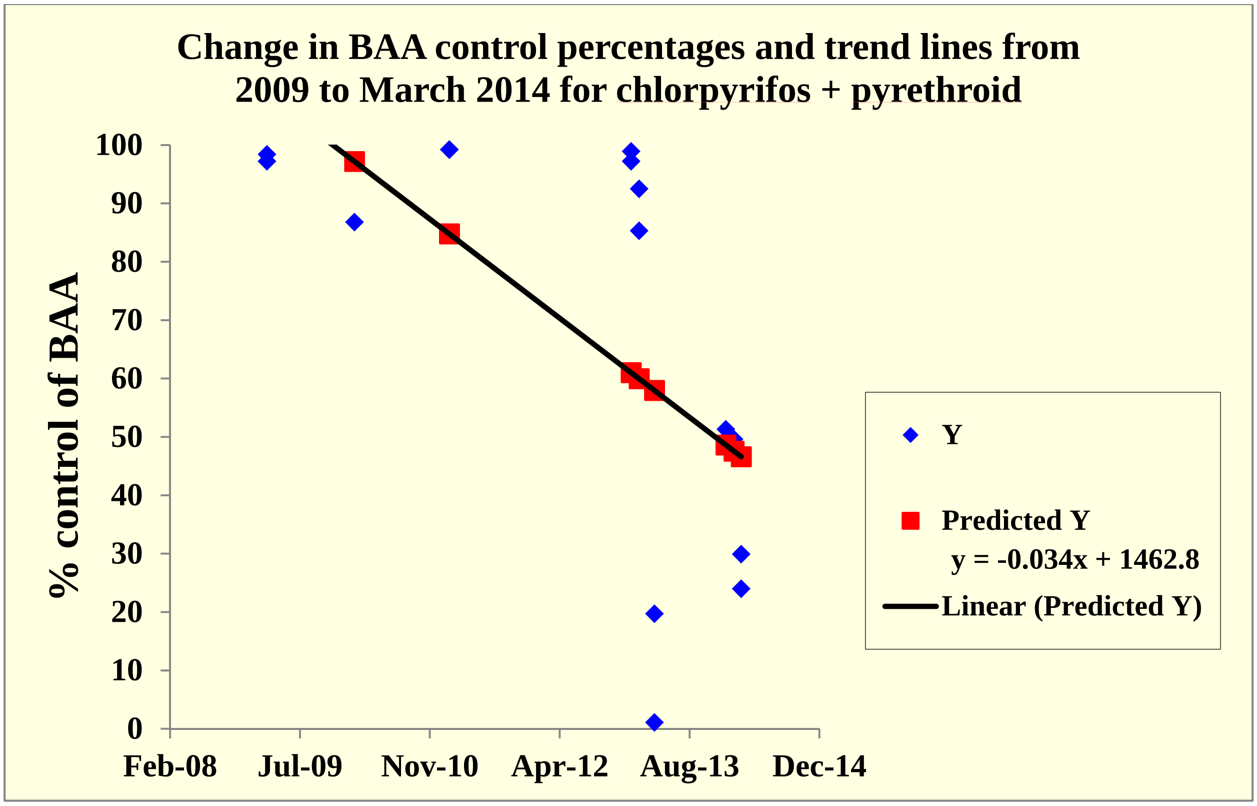

Figure 5. BAA control percentages and trend lines from 2009 to March 2014 for pyrethroid insecticides (gama-cyhalothrin, lambda-cyhalothrin or zeta-cypermethrin) combined with the organophosphate insecticide chlorpyrifos; IRAC #'s 3A+1B.

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	7265.18	7265.18	9.502579	0.008107
Residual	14	10703.67	764.5482		
Total	15	17968.85			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1462.759	452.6954	3.231221	0.006034	491.8238	2433.694	491.8238	2433.694
X Variable 1	-0.03396	0.011017	-3.08263	0.008107	-0.05759	-0.01033	-0.05759	-0.01033