Insecticide Efficacy During High Summer Temperatures for Low Desert Alfalfa Insect Control, 2018

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ABSTRACT

Four insecticides with differing active ingredients (DiPel® DF =*Bacillus thuringensis*; Coragen® = chlorantraniliprole; Steward® EC = indoxacarb; Zylo™ = methoxyfenozide) were applied to alfalfa infested with alfalfa butterfly caterpillars in early July 2018 when air temperatures exceeded 115ºF. All products provided excellent control of alfalfa butterfly caterpillars, *Colias eurytheme*, indicating that high temperature did not effect product efficacy. All active ingredients with the exception of DiPel® DF also provided control of beet armyworms (*Spodoptera exigua*) and yellow-striped armyworms (*Spodoptera ornithogalli*). Steward® EC was noted to reduce numbers of *Empoasca* leafhoppers, white-marked fleahoppers (*Spanagonicus albofasciatus*) and western big-eyed bugs (*Geocoris pallens*), with this treatment also resulting in highest crude protein of harvested alfalfa hay. Application of Zylo™ resulted in highest numbers of white-marked fleahoppers and *Empoasca* leafhoppers, but also had the highest relative feed value. Highest yields were noted from the DiPel® DF treatment. All treatments resulted in slightly higher alfalfa hay yields and/or quality.

INTRODUCTION

A number of insect species, especially caterpillars, can be summer pests of low desert alfalfa production. These caterpillar species include the alfalfa butterfly, *Colias eurytheme* Boisd., the beet armyworm *Spodoptera exigua* (Hübner), the western yellow-striped armyworm *Spodoptera praefica* Grote, the yellow-striped armyworm *Spodoptera ornithogalli* Guenée, and the dingy cutworm *Feltia jaculifera (*Guenée*).*

Summer conditions in low desert alfalfa production areas often consists of high temperatures, low humidity and intense ultraviolet radiation. The temperature factor has been noted to negatively effect insecticidal performance of certain products such as many synthetic pyrethroids, while increasing efficacy of other insecticides (Khan and Akram, 2014, and references therein).

These environmental factors can also affect insect development, survival and biological interactions. High temperatures and low humidity are also factors that are noted as favorable for outbreaks of alfalfa caterpillars, *Colias eurytheme* (UC IPM website), due to their negative effects on *Trichogramma spp.* wasps that parasitize alfalfa butterfly eggs. Low humidity (which often accompanies high desert temperatures above 110ºF) were often noted to be fatal to maturing *T. semifumatum* in laboratory studies (Stern and Bowen, 1963).

Trichogramma semifumatum (Perkins) is the major alfalfa butterfly egg parasitoid in the low deserts of California, often credited with keeping alfalfa butterfly populations from reaching

economic thresholds. Reports of near 100% egg parastism have been noted in late summer in the low desert (Stern and Bowen, 1963) when humidity levels are often higher and temperatures are slighlty lower than typically experienced in June-July.

This experiment was initiated to document the efficacy of current insecticide active ingredients recommended by the University of California for alfalfa butterfly caterpillars and armyworms. These insecticide active ingredients are considered non-disruptive to beneficial insects. This experiment was also intended to further document the insecticide interactions, pest levels, beneficial insect populations and resulting alfalfa yields, and quality when these products are applied to alfalfa during very high summer temperatures in the low desert.

METHODS and MATERIALS

An alfalfa field located located northwest of Blythe, California, was selected for this experiment, and had been irrigated for the first time in the cutting cycle. Alfalfa caterpillars were prevalent and *Trichogramma* wasps were expected to be limited by high temperatures.

A number of insects, many with chewing mouthparts, were evident on the date of application. Insect pests that were most prevalent (listed as #/sweep) late afternoon July 6 were alfalfa butterfly caterpillars (4.1), pale striped flea beetles (4.1), *Empoasca* spp. leafhoppers (2.1) and a few beet armyworms/yellow striped armyworms (0.4). The most prevalent beneficial insects noted in sweep samples were minute pirate bugs (1.1/sweep) and big-eyed bugs (0.3/sweep).

Treatments were applied late morning and early afternoon of July 6, 2018. Alfalfa stem heights in the field on this date ranged from 7-14 inches, with the vast majority of stems being 10-11 inches tall (7.5-8.5" of regrowth). High temperature later that day reached 122ºF on some car thermometers, was noted at 119ºF in downtown Blythe, and was officially recorded as 116ºF by the National Weather Service (NWS).

The NWS high temperature the previous day (July 5) was 115ºF, and temperatures after the application were 114ºF and 112ºF as highs and recorded lows of 88ºF and 92ºF on July 7 and 8 respectively, providing several consecutive days of high temperatures of at least 112ºF. These levels provided adequate heat levels to test interactions of high temperature and insecticide.

Insecticide treatments applied were Coragen®, DiPel® DF, Steward® EC and Zylo™. All treatments were applied with a battery powered sprayer equipped with a boom and four (4) 8002-VS nozzles calibrated to deliver 16.8 gpa. Plots were 25 x 28 feet in size, with treatments having four replications utilizing a randomized complete block design.

All treatments had the modified ethylated vegetable oil (ESO) concentrate Hasten-EA™ (Wilbur-Ellis Company) added as an adjuvant at 1 pt/acre (0.70 v/v). This product contains canola oil and is 100% ethylated seed oil/polyoxyalkylene fatty ester, and provides excellent wetting and penetration of insecticides. It was also used to reduce product evaporation after applicaiton under the high temperatures and low humidity conditions.

Coragen® (marketed by FMC Corporation) contains 1.67 lbs/gallon of the active ingredient chlorantraniliprole as a suspension concentrate. While labeled in alfalfa and most crops for control of grasshoppers and various caterpillars, a few beetles were also noted on the label (such as Colorado potato beetle on potatoes, and Japanese beetle on strawberries), thus indicating that control of coleopteran insects in alfalfa may also be achieved. Coragen® was applied at the rate of 3.5 oz./acre.

DiPel® DF (Valent BioSciences Corporation) is a dry flowable biological insecticide which contains 54% *Bacillus thuringiensis*, subsp. *kurstaki*, strain ABTS-351, fermentation solids, spores and insecticidal toxins, with a potency of 32,000 cabbage looper units per mg (14.5 billion/lb.). This product is approved for use in organic and conventional crops and is labeled for lepidopterous insect control. It was applied at a rate of 0.5 lbs. (8.0 oz.)/acre, although higher rates are noted on the label recommendations for control of armyworms (*Spodoptera* spp.).

Steward® EC (marketed by FMC Corporation) contains 1.25 lbs./gallon of the active ingredient indoxacarb. This product is labeled for control of caterpillars of alfalfa butterflies and several other lepidopterous species (beet armyworm, western yellow-striped armyworm, granulate cutworm), larval stages of alfalfa weevils, and suppression of potato leafhoppers (*Empoasca* spp.). It was used at the rate of 8 oz./acre.

A combination treatment of 8 oz./acre of Dipel® DF and 3.2 oz./acre of Steward® EC was also included in the experiment.

Zylo™ Insecticide (marketed by UPI) is an insecticide that contains methoxyfenozide as the active at the rate of 2.0 lbs/gallon. Methoxyfenozide mimics the action of the molting hormone of various lepidopterous caterpillars, thus resulting in a premature and lethal molt after injested. Alfalfa caterpillar, various armyworms, alfalfa looper, and webworms are listed as controlled pests on the Zylo™ label. It is not expected to provide control of adult insects. This product was used at 8 oz./acre.

Plots were sampled at 3, 7, 10, and 14 days post treatment with a 15" diameter sweep net and ten (10) sweeps/plot using a 90° straight sweep (approximately 3 foot length). Upper vegetation was deeply sampled (up to the top 15 inches of stem height), thus collecting many insects located deeper in the canopy than at growing tips

After sweeping, collected insects were transferred to plastic containers and returned to the laboratory and placed in freezers to kill the insects. Containers were then removed, and insects were then separated to species, counted and data recorded. Caterpillars were further separated into three (3) class sizes (small, medium, large) to help provide data on interactions between insecticides and caterpillar size. Leafhoppers were also separated into nymphs and adults.

Yield data were collected on July 20 (14 days post treatment) by placing a PVC frame square (12.625 x 12.625" interior) or rectangle (24" x 18" interior) in two locations in each plot. All plots in the first replicate had both a square and rectangle area harvested, while all other plots had two rectangular frame areas harvested. After the frames were dropped, alfalfa stems were

straightened to an upright orientation. Stems remaining within the frame were cut with a serrated knife about at approximately 2 inches above the soil line, similar to a commercial harvest.

Cut alfalfa from each plot was placed into a paper grocery bag, dried and alfalfa hay was weighed. NIR analyses (Stanworth Crop Consultants, Blythe, CA) were then conducted on each sample to obtain quality data.

Statistical analyses of data and treatment mean separations were conducted using Tukey's Honestly Significant Difference (HSD) test (JMP Pro 13.0.0).

RESULTS and DISCUSSION

Alfalfa Butterfly Caterpillars

High numbers of alfalfa butterfly caterpillars at the beginning of the experiment allowed for high confidence in experimetnal results when comparing product efficacy from the first two sample dates (July 9 and 13), when caterpillars averaged 90.25 and 46.75/10 sweeps respectively in untreated alfalfa. All treatments resulted in excellent control (95-100%) of alfalfa butterfly caterpillars on the first three sample dates (Tables 1-4).

Very few alfalfa butterfly caterpillars remained by the July 20 (14 days post treatment) sample date, as alfalfa butterflies prefer to lay eggs early in the regrowth cycle on the new growth alfalfa that is less than 6 inches in height (University of California Integrated Pest Management Program). Alfalfa stems averaged 10-11 inches in height when treatments were applied on July 6, and had approximately 8 inches of regrowth on that date.

Table 1. Mean number of small (<0.5 inches) alfalfa butterfly caterpillars (#/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

		Sample Date			
Insecticide and Rate/Acre		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.25a	0.00a	0.00a	0.00a
DiPel® DF	8 oz.	0.0a	0.00a	0.00a	0.00a
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.5a	0.00a	0.00a	0.00a
Steward® EC	8 oz.	0.25a	0.00a	0.00a	0.00a
Zylo™	8 oz.	0.75a	0.00a	0.00a	0.00a
Untreated	-----	45.25 b	14.25 b	1.00 b	0.50a
	p value	*<0.0001*	*<0.0001*	*<0.01*	*0.07*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 2. Mean number of medium (0.5-1.0") alfalfa butterfly caterpillars (#/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.00a	0.00a	0.00a	0.00a
DiPel® DF	8 oz.	0.25a	0.00a	0.00a	0.00a
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.25a	0.00a	0.25a	0.00a
Steward® EC	8 oz.	0.00a	0.50a	0.00a	0.00a
Zylo™	8 oz.	1.00a	0.00a	0.00a	0.25a
Untreated	-----	30.75 b	24.5 b	2.25 b	0.25a
	P value	*<0.0001*	*<0.0001*	*0.0002*	*0.82*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 3. Mean number of large (> 1.0") alfalfa butterfly caterpillars (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	Jul 13	July 16	July 20
Coragen®	3.5 oz.	0.00a	0.00a	0.00a	0.00a
DiPel® DF	8 oz.	0.00a	0.00a	0.00a	0.00a
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.00a	0.00a	0.00a	0.00a
Steward® EC	8 oz.	0.00a	0.00a	0.00a	0.00a
Zylo™	8 oz.	0.00a	0.00a	0.00a	0.00a
Untreated	-----	14.25 b	8.00 b	1.75a	0.00a
	P value	*0.0001*	*0.0002*	*0.33*	-----

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 4. Mean number of alfalfa butterfly caterpillars (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.25a	0.00a	0.00a	0.00a
DiPel® DF	8 oz.	0.25a	0.00a	0.00a	0.00a
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.75a	0.00a	0.25a	0.00a
Steward® EC	8 oz.	0.25a	0.50a	0.00a	0.00a
Zylo™	8 oz.	1.75a	0.00a	0.00a	0.25ab
Untreated	-----	90.25 b	46.75 b	5.00 b	0.75 b
	P value	*<0.0001*	*<0.0001*	*<0.0001*	*0.02*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Beet Armyworms

Beet armyworm caterpillars were not as prevalent in this experiment as the alfalfa butterfly caterpillars, but enough were present to detect efficacy differences. Most treatments resulted in >90% control of small (,0.5 inches) beet armyworms at 3 days post treatment (Table 5) with the exception of treatments that included DiPel. The DiPel only treatment had less than 33% on this date of small and total beet armyworms (Table 8). Addition of 3.2 oz./acre of Steward to DiPel increased efficacy by a minimum of 75% (Tables 5-6, 8).

Mean number of total beet armyworm caterpillars were greater in Dipel only treated plots than untreated plots on July 13 and 16 (Table 8, although the reason for this is unknown. Coragen and Zylo™ treatments resulted in the fewest total beet armyworm caterpillars on July 9 and 13 (Table 8), while Coragen had the fewest on July 16 and 20 (Table 8). Statistical differences from these treatments for total beet armyworm larvae when compared with untreated alfalfa was noted only on July 9 (Table 8).

Yellow-Striped Armyworms

Yellow-striped armyworms were present but not prevalent in July 9 (3 days post treatment) samples, but numbers collected increased after this sample date, primarily those of small caterpillars indicating eggs being laid and hatching (Table 9). Very few large (>1.0 inch) yellow-striped armyworms were present in this experiment (Table 11).

Highest numbers of small (<0.5 inches) yellow striped armyworms were noted from alfalfa treated with DiPel on July 9 and 13 (Tables 9-12) than untreated alfalfa, similar to that noted from this insecticide for control of beet armyworms.

All treatments with the exception of the DiPel DF only treatment resulted in significantly fewer total yellow striped armyworms than the untreated check on July 16 (Table 12). Caterpillar numbers increased in all treated plots from July 16-20, especially those of small caterpillars (Table 9), indicating that treatments were losing efficacy at this point of the experiment. Fewest small yellow-striped armyworms were noted due to Coragen and the 8 oz./acre rate of Steward treatments at 14 days post treatment (Table 9-12), with these chemistries resulting in a statistically fewer total yellow-striped armyworm caterpillars (Table 12).

Combined Armyworms

Western yellow-striped armyworms were only occasionally collected during this experiment, and were not present in high enough populations for statistical analyses. Numbers of all three armyworm caterpillars were therefore combined for a potential better understanding of insecticide efficacy.

Analyses of total armyworm caterpillars resulted in statistical differences on each of the four sample dates (Table 13). The pattern of the DiPel DF treatment resulting in similar or higher armyworm caterpillars than in untreated alfalfa was noted across all sample dates. All other treatments resulted in significantly fewer armyworms through 10 days post treatment (Table 13). At 14 days post treatment only the Coragen and the 8 oz./acre rate of Steward treatments still resulted in significantly fewer armyworms than untreated alfalfa (Table 13).

Table 5. Mean number of small (<0.5") beet armyworms (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

		Sample Date			
Insecticide and Rate/Acre		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.50ab	0.00a	0.00a	0.25a
DiPel®	8 oz.	5.50 bc	6.00 b	2.75 b	1.50a
DiPel® + Steward®	8 oz. 3.2 oz.	1.25ab	1.00a	0.25a	2.25a
Steward® EC	8 oz.	0.50ab	1.50a	0.75a	1.00a
Zylo™	8 oz.	0.25a	0.00a	0.50a	3.50a
Untreated	-----	8.00 c	3.25ab	0.50a	2.25a
	P value	*0.002*	*0.004*	*0.002*	*0.16*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 6. Mean number of medium size (0.5-1.0") beet armyworms (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.00a	0.00a	0.25a	0.25a
DiPel® DF	8 oz.	1.00a	1.50a	0.25a	0.25a
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.25a	0.00a	1.00a	0.50a
Steward® EC	8 oz.	0.00a	0.00a	0.00a	0.50a
Zylo™	8 oz.	0.00a	0.00a	0.00a	0.50a
Untreated	-----	1.00a	0.00a	0.75a	1.00a
	P value	*0.69*	*0.67*	*0.45*	*0.73*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 7. Mean number of large (>1.0") beet armyworm caterpillars (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.00a	0.00a	0.00a	0.00a
DiPel® DF	8 oz.	0.00a	0.25a	0.00a	0.25a
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.00a	0.00a	0.00a	0.00a
Steward® EC	8 oz.	0.00a	0.00a	0.00a	0.00a
Zylo™	8 oz.	0.00a	0.00a	0.25a	0.25a
Untreated	-----	0.00a	0.00a	0.50a	1.25a
	P value	-----	*0.53*	*0.26*	*0.31*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 8. Mean total beet armyworm caterpillars (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.50a	0.00a	0.25a	0.50a
DiPel® DF	8 oz.	6.50 bc	7.75 b	3.00 b	2.00a
DiPel® DF + Steward®	8 oz. 3.2 oz.	1.50ab	1.00a	1.25ab	2.75a
Steward® EC	8 oz.	0.50a	1.50a	0.75a	1.50a
Zylo™	8 oz.	0.25a	0.00a	0.75a	4.25a
Untreated	-----	9.00 c	4.75ab	1.75ab	4.50a
	P value	*<0.001*	*0.002*	*0.004*	*0.19*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 9. Mean number of small (<0.5 inches) yellow-striped armyworm caterpillars (#/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.25a	0.25a	3.00ab	3.25a
DiPel® DF	8 oz.	3.25a	16.00a	8.75ab	10.25a
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.00a	1.00a	1.75a	8.00a
Steward® EC	8 oz.	0.00a	0.00a	1.50a	2.75a
Zylo™	8 oz.	0.50a	1.00a	3.75ab	9.00a
Untreated	-----	1.00a	9.25a	9.75 b	12.25a
	p value	*0.55*	*0.07*	*0.02*	*0.07*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 10. Mean number of medium (0.5-1.0") yellow-striped armyworm caterpillars (#/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.00a	0.00a	0.00a	0.25a
DiPel® DF	8 oz.	0.25a	1.00a	0.50ab	3.00 b
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.00a	0.00a	0.50ab	1.00ab
Steward® EC	8 oz.	0.00a	0.50a	0.00a	0.50ab
Zylo™	8 oz.	0.00a	0.00a	0.00a	2.00ab
Untreated	-----	0.25a	0.75a	4.00 b	2.25ab
	P value	*0.82*	*0.47*	*0.04*	*0.036*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 11. Mean number of large (>1.0") yellow-striped armyworm caterpillars (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	Jul 13	July 16	July 20
Coragen®	3.5 oz.	0.00	0.00a	0.00a	0.25a
DiPel® DF	8 oz.	0.00	0.00a	0.00a	0.50a
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.00	0.00a	0.00a	0.25a
Steward® EC	8 oz.	0.00	0.00a	0.00a	0.00a
Zylo™	8 oz.	0.00	0.00a	0.25a	0.00a
Untreated	-----	0.00	0.00a	0.00a	0.00a
	P value	------	------	*0.53*	*0.72*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 12. Mean number of yellow-striped armyworm caterpillars (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.25a	0.25a	3.00a	3.75ab
DiPel® DF	8 oz.	3.50a	17.00a	9.25ab	13.75 bc
DiPel® DF + Steward*	8 oz. 3.2 oz.	0.00a	1.00a	2.25a	9.25abc
Steward® EC	8 oz.	0.00a	0.00a	1.50a	3.25a
Zylo™	8 oz.	0.50a	1.00a	4.00a	11.00abc
Untreated	-----	1.25a	10.00a	13.75 b	14.50 c
	P value	*0.46*	*0.06*	*0.0014*	*0.26*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 13. Mean total number of armyworm (beet, yellow-striped, and western yellow-striped) caterpillars (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.75a	0.25a	3.25a	4.25a
DiPel® DF	8 oz.	10.00 b	24.75 b	12.50 bc	15.75ab
DiPel® DF + Steward*	8 oz. 3.2 oz.	1.50a	2.00a	3.50ab	12.50ab
Steward® EC	8 oz.	0.50a	1.50a	2.25a	4.75a
Zylo™	8 oz.	0.75a	1.00a	4.75ab	15.50ab
Untreated	-----	10.25 b	14.75ab	15.50 c	19.50 b
	P value	*0.01*	*<0.01*	*<0.03*	*0.01*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Empoasca spp. Leafhoppers

Empoasca leafhoppers, thought to be the Mexican potato leafhopper (*E. mexara*), were present throughout the experiment, with numbers of leafhoppers increasing during the first 10 days after application. While insecticides used in this field trial were expected to control caterpillars, few if any, effects on *Empoasca* leafhoppers were expected. Data were collected on both nymphs and adult *Empoasca* leafhoppers in this experiment.

Highest numbers of *Empoasca* leafhoppers were noted in treatments containing DiPel DF on July 9 (3 DAT) with the DiPel DF only treatment resulting in significantly more *Empoasca* leafhopper nymphs (6.26/10 sweeps) than noted from alfalfa treated with the 8 oz./acre rate of Steward EC or Zylo™ treatments (0.75) (Table 14). Numbers of *Empoasca* leafhopper nymphs increased between three and seven days post treatment with highest number of nymphs being collected from Zylo™ treated alfalfa (64.5/10 sweeps), almost double that collected from untreated alfalfa (30.0) at seven days post treatment (Table 14).

Alfalfa plots that had received a treatment that contained Steward EC had fewest nymphs on this and all subsequent sample dates (Table 14), with these levels being highly significantly less than the noted from Zylo™ treated alfalfa (91.5) at 10 days post treatment, and approximately 50% less than untreated alfalfa on this date (Table 14).

DiPel DF and Coragen treatments resulted in numbers of *Empoasca* leafhopper nymphs that were very similar to that collected from untreated alfalfa, while these data indicating that Steward EC did have some activity against *Empoasca* leafhoppers. Previous low desert research had also noted some activity of Steward EC at 6.7 oz./acre against *Empoasca* leafhoppers (Rethwisch et al., 2007).

Zylo™ treated alfalfa contained the highest numbers of total *Empoasca* leafhoppers at 10 and 14 days post treatment (Table 15-16). The reason for this is unclear, but this treatment and/or inert ingredients may have resulted in alfalfa foliage that was more attractive to adult leafhoppers for infestation of plots and/or oviposition, however, increase of adult leafhoppers (~80/10 sweeps) from 7-10 days post treatment were very similar in the untreated, 8 oz../acre rate of Steward EC and Zylo™ treated alfalfa (Table 15).

The low numbers of *Empoasca* leafhoppers in untreated alfalfa at three days post treatment are thought due to high numbers of alfalfa caterpillars that may have been disturbing leafhoppers and/or eaten the foliage (Tables 15-16).

Table 14. Mean number of *Empoasca* leafhopper nymphs (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	1.25ab	46.00a	60.25ab	52.50a
DiPel® DF	8 oz.	6.25 b	64.50a	57.25ab	38.25a
DiPel® DF + Steward®	8 oz. 3.2 oz.	2.50ab	23.50a	39.75a	35.00a
Steward® EC	8 oz.	0.75a	13.75a	32.75a	24.75a
Zylo™	8 oz.	0.75a	57.50a	91.50 b	52.0a
Untreated	-----	1.25ab	30.00a	69.5ab	47.0a
	P value	*0.04*	*0.052*	*0.0014*	*0.06*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 15. Mean number of adult *Empoasca* leafhoppers (numbers/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	28.50a	34.00a	98.0a	116.50ab
DiPel®	8 oz.	23.00a	45.75a	100.5a	83.50ab
DiPel® + Steward®	8 oz. 3.2 oz.	25.75a	33.5a	104.0a	88.75ab
Steward® EC	8 oz.	20.75a	28.25a	104.8a	73.25a
Zylo™	8 oz.	23.75a	42.50a	129.0a	162.50 b
Untreated	-----	7.50a	22.25a	108.8a	111.50ab
	P value	*0.12*	*0.20*	*0.54*	*0.023*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 16. Mean total *Empoasca* leafhoppers (numbers/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	29.75a	80.00a	158.3ab	169.00ab
DiPel®	8 oz.	29.25a	110.25a	157.8ab	121.75ab
DiPel® + Steward®	8 oz. 3.2 oz.	28.25a	57.00a	143.8ab	123.75ab
Steward® EC	8 oz.	21.50a	42.00a	137.5a	98.00a
Zylo™	8 oz.	24.50a	100.00a	220.5 b	214.50 b
Untreated	-----	8.75a	52.25a	178.3ab	158.50ab
	P value	*0.18*	*0.08*	*0.04*	*0.01*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Clover and other non-Empoasca leafhoppers

Numbers of adult and nymphal clover leafhoppers (*Aceratagilla sanguinolenta*) and other non-*Empoasca* leafhoppers were not separated in this experiment. Insect populations peaked at seven (7) days post treatment, declined by over 50% by 10 days post treatment and then increased by 20 days post treatment (Table 17).

Significant differences in clover and other non-*Empoasca* sp. leafhoppers were not noted until 14 days post treatment, when both the DiPel DF and the 8 oz./acre Steward EC treatments resulted in less leafhoppers than untreated alfalfa (Table 17). The combination treatment of two chemistries had very similar numbers of leafhoppers as the untreated check however.

Whitemarked Fleahoppers

Adult whitemarked fleahoppers were collected and increased in numbers throughout the study, with highest numbers noted at 14 days post treatment (Table 18). Fewest numbers of whitemarked fleahoppers were noted from alfalfa that was treated with an insecticide that contained Steward EC on all four sample dates (Table 18).

Zylo™ and Coragen treatments resulted in in highest white-marked fleahoppers at 7, 10 and 14 days post treatment, with the Zylo™ treatment resulting significantly more than the 8 oz./acre Steward EC at 7 and 10 days post treatment (Table 18). Numbers more than doubled from 10-14 days post treatment in untreated and treated alfalfa with the exception of the 8 oz./acre rate of Steward EC, indicating this chemistry still had some activity against white-marked fleahoppers (Table 18), as this chemistry did not have more beneficial insects than other chemistries.

Table 17. Mean number of clover and other non-*Empoasca* spp. leafhoppers (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	12.00a	41.50a	10.75a	22.50abc
DiPel®	8 oz.	11.50a	42.75a	14.50a	20.50ab
DiPel® + Steward®	8 oz. 3.2 oz.	11.25a	50.50a	21.50a	33.00abc
Steward® EC	8 oz.	7.50a	40.00a	16.50a	20.25a
Zylo™	8 oz.	14.25a	55.25a	18.75a	33.75 bc
Untreated	-----	8.00a	43.50a	20.25a	34.50 c
	P value	*0.14*	*0.70*	*0.16*	*0.034*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 18. Mean white-marked fleahoppers (numbers/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	9.50a	7.00ab	7.00ab	43.25a
DiPel®	8 oz.	11.00a	5.50ab	5.50ab	19.50a
DiPel® + Steward®	8 oz. 3.2 oz.	3.25a	2.25a	5.25ab	17.75a
Steward® EC	8 oz.	3.75a	2.25a	3.00 b	6.75a
Zylo™	8 oz.	8.25a	11.75 b	10.50a	58.50a
Untreated	-----	5.00a	8.75ab	6.00ab	34.00a
	P value	*0.11*	*0.03*	*0.02*	*0.12*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Three cornered alfalfa hoppers

Adult three cornered alfalfa hoppers (3CAH) were prevalent during this experiment, with more noted earlier in the experiment (July 9 and 13, 3 and 7 days post treatment) than at 10 and 14 days post treatment (July 16 and 20).

Untreated alfalfa had fewer 3CAH than noted from all treatments at 3 days post treatment (July 9), similar to that noted for adult *Empoasca* leafhoppers on this sample date. This may have been due to the high numbers of alfalfa butterfly caterpillars present in the untreated plots on this sample date.

Two treatments (DiPel DF and Zylo™) resulted in significantly more 3CAH/10 sweeps than untreated alfalfa (approximately 73 vs. 36.5) on the first (July 9) sample date (Table 19).

Mean number of 3CAH were similar for treated and untreated alfalfa on all subsequent sample dates. Significant differences were not noted on any other sample date, although fewest 3CAH were usually noted from untreated alfalfa (Table 19). Highest mean number of 3CAH were noted in Zylo™ treated plots on July 13, 16 and 20 (Table 19).

Table 19. Mean adult three-cornered alfalfa hoppers (#/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

		Sample Date			
Insecticide and Rate/Acre		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	51.75ab	52.75a	29.00a	33.25a
DiPel®	8 oz.	73.00 b	51.75a	33.50a	33.25a
DiPel® + Steward®	8 oz. 3.2 oz.	52.5ab	46.50a	37.50a	31.00a
Steward® EC	8 oz.	47.25ab	52.75a	32.25a	27.25a
Zylo™	8 oz.	72.75 b	55.25a	43.75a	40.50a
Untreated	-----	36.50a	46.00a	24.25a	28.50a
	P value	*0.02*	*0.85*	*0.22*	*0.42*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Pale Striped Flea Beetles

Treatments had little effect on pale striped flea beetles, although all treatments did result in slightly more beetles than collected on July 9 (3 days post treatment) than collected from untreated alfalfa (Table 20), thought partially due to foliage being consumed and other activity in untreated plots by alfalfa butterfly caterpillars.

While no treatment resulted in statistically fewer pale striped flea beetles than collected from untreated alfalfa during this experiment, a statistical difference was noted on July 13 between DiPel DF (56.0 flea beetles/10 sweeps) and the DiPel + 3.2 oz./acre of Steward EC (32.75). The reason for this is unknown.

The fewest adult pale striped flea beetles on July 16 and 20 were noted from the 8 oz./acre of Steward EC treatment on July 16 (40.25) and 20 (46.25), with highest mean numbers noted from Zylo™ (70.0) and Coragen treatments (68.5/10 sweeps) on July 20 (Table 20).

Table 20. Mean number of adult pale striped flea beetles (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

		Sample Date			
Insecticide and Rate/Acre		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	48.75a	36.25ab	47.25a	68.5aa
DiPel®	8 oz.	45.5a	56.00 b	42.75a	56.50a
DiPel® + Steward®	8 oz. 3.2 oz.	44.5a	32.75a	47.75a	52.50a
Steward® EC	8 oz.	45.75a	40.75ab	40.25a	46.25a
Zylo™	8 oz.	44.0a	42.75ab	50.25a	70.00a
Untreated	-----	39.5a	33.5ab	52.0a	63.75a
	P value	*0.76*	*0.049*	*0.44*	*0.09*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Minute pirate bugs

Adult minute pirate bugs, *Orius tristicolor* (White), were fairly prevalent at all four sample dates (Table 22), and increased in number as the experiment progressed. At 3 and 7 days post treatment, highest numbers of adult minute pirate bugs were collected from alfalfa treated with an insecticide that contained Steward EC (Table 22), with numbers on July 13 being approximately double that collected from untreated alfalfa (Table 22).

Treatments containing Steward EC resulted in the lowest number of minute pirate bug nymphs at 7 days post treatment however, with fewer nymphs noted as the rate of Steward EC increased (Table 21). The reason for divergence in adult vs. nymph populations with this particular chemistry is unknown. Zylo™ treated alfalfa had significantly more minute pirate bug nymphs than collected for alfalfa treated with the 8 oz./acre rate of Steward EC at 7 days post treatment (Table 21).

Differences were noted between the two treatments which contained Steward at 10 days post treatment. The 8 oz./acre rate of Steward EC had significantly fewer minute pirate bug nymphs (6.25/10 sweeps) than the DiPel DF + Steward EC 3.2 oz./acre treatment (17.25/10 sweeps) on July 16 (Table 21).

No statistical differences were noted for total minute pirate bugs on any sample date during this experiment (Table 23).

Table 21. Mean number of *Orius* nymphs (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

		Sample Date			
Insecticide and Rate/Acre		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	1.00a	3.75ab	10.25ab	11.00ab
DiPel® DF	8 oz.	0.50a	5.75ab	11.00ab	7.00 b
DiPel® DF + Steward®	8 oz. 3.2 oz.	0.00a	2.75ab	17.25a	16.25a
Steward® EC	8 oz.	0.25a	1.75 b	6.25 b	10.50ab
Zylo™	8 oz.	0.25a	9.75a	11.25ab	12.75ab
Untreated	-----	0.50a	4.25ab	13.75ab	12.50ab
	P value	*0.59*	*0.04*	*0.023*	*0.037*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 22. Mean number of adult *Orius* (numbers/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	7.75a	7.25a	16.75a	23.50a
DiPel®	8 oz.	9.50a	9.25a	20.00a	13.25a
DiPel® + Steward®	8 oz. 3.2 oz.	13.75a	11.00a	10.50a	26.75a
Steward® EC	8 oz.	16.5a	12.50a	14.75a	22.25a
Zylo™	8 oz.	10.5a	9.75a	17.00a	24.25a
Untreated	-----	8.5a	5.75a	20.50a	21.75a
	P value	*0.11*	*0.32*	*0.13*	*0.25*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 23. Mean total *Orius* (numbers/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	8.75a	11.00a	27.00a	34.50a
DiPel®	8 oz.	10.00a	15.00a	31.00a	20.25a
DiPel® + Steward®	8 oz. 3.2 oz.	13.75a	13.75a	27.75a	43.00a
Steward® EC	8 oz.	16.75a	14.25a	21.00a	32.75a
Zylo™	8 oz.	10.75a	19.50a	28.25a	37.00a
Untreated	-----	9.00a	10.00a	34.25a	34.25a
	P value	*0.14*	*0.29*	*0.17*	*0.08*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Western Big-eyed Bugs

Western big-eyed bugs (*Geocoris pallens* Stål) were present during this experiment, with adults more prevalent than nymphs. Highest nymph numbers were noted at 7 and to a lesser extent 14 days post treatment, but declined between 7-10 days post treatment (Tables 22-24). This was also true for adult western big-eyed bugs and was similar to the population trends noted for the non-*Empoasca* leafhoppers (Table 17).

While no significant differences in *Geocoris* numbers were noted at three (3) days post treatment, such differences were noted at seven (7) days. Highest adult numbers (28+/10 sweeps) and total big-eyed bugs (36+/10 sweeps) were noted from DiPel DF only treated alfalfa and untreated alfalfa (Tables 25-26).

Both treatments containing Steward EC resulted in significantly fewer (approximately 60% less) big-eyed bugs adults (10-12/10 sweeps) and total big-eyed bugs (13-16/ 10 sweeps) at 7 days post treatment (Tables 25-26) compared with DiPel DF only and untreated alfalfa.

Fewest adult western big-eyed bugs were also collected from alfalfa treated with an insecticide containing Steward EC at 10 days post treatment (Table 25). Activity of Steward EC against this species had previously been noted in other local studies (Rethwisch et al., 2007).

Coragen and Zylo™ treatments resulted in big-eyed bug populations very similar to that of untreated alfalfa at 10 and 14 days post treatment, and while numerically less at 7 days the differences were not statistically significant (Tables 25-26).

Table 24. Mean number of big-eyed bug nymphs (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

		Sample Date			
Insecticide and Rate/Acre		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.00a	6.50a	2.50a	8.25a
DiPel® DF	8 oz.	0.25a	8.50a	2.00a	4.50a
DiPel® DF + Steward®	8 oz. 3.2 oz.	0.25a	3.50a	2.75a	7.50a
Steward® EC	8 oz.	0.00a	3.75a	3.50a	5.50a
Zylo™	8 oz.	0.50a	8.25a	3.00a	9.00a
Untreated	-----	0.25a	5.25a	2.75a	4.00a
	P value	*0.78*	*0.41*	*0.82*	*0.47*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 25. Mean number of adult big-eyed bugs (numbers/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	1.00a	15.25abc	11.00a	13.00a
DiPel®	8 oz.	2.50a	28.25ab	12.75a	11.25a
DiPel® + Steward®	8 oz. 3.2 oz.	1.25a	10.00 c	6.75a	12.00a
Steward® EC	8 oz.	2.00a	12.00 bc	7.75a	10.25a
Zylo™	8 oz.	2.50a	19.00abc	11.25a	14.25a
Untreated	-----	3.00a	31.25a	10.0a	17.25a
	P value	*0.42*	*0.02*	*0.12*	*0.21*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 26. Mean total big-eyed bugs (numbers/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	1.00a	21.75ab	13.50a	21.25a
DiPel®	8 oz.	2.75a	36.75a	14.75a	15.75a
DiPel® + Steward®	8 oz. 3.2 oz.	1.50a	13.50 b	9.50a	19.50a
Steward® EC	8 oz.	2.00a	15.75 b	11.25a	15.75a
Zylo™	8 oz.	3.00a	27.25ab	14.25a	23.25a
Untreated	-----	3.25a	36.50a	12.75a	21.25a
	P value	*0.43*	*0.02*	*0.49*	*0.40*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Damsel bugs

Numbers of damsel bugs, while present during the experiment, were fairly low, and also exhibited population peaks at 7 and 14 days post treatment as noted for several other insects in this study. No statistical differences were noted, although non-Steward containing treatments did have numerically more nymphs than untrerated alfalfa at 7 days post treatment. Treatments containing Steward EC resulted in similar to slightly fewer damselbug nymphs than collected from untreated alfalfa on this sample date (Table 27).

Numbers of adult damsel bugs were very similar among treatments and compared with untreated alfalfa on all four sample dates (Table 28). Total numbers of damsel bugs reflected the nymph population, as there were usually more nymphs collected than adults throughout the study (Table 29).

Total Beneficial Bugs

Total beneficial bugs (minute pirate bugs, western big-eyed bugs, damsel bugs) in this study consisted of over 50% western big-eyed bugs at 7 days post treatment, but were almost 50% minute pirate bugs by 14 days post treatment, while western big-eyed bugs represented approximately 30% of the beneficial bug complex from the latter sample.

Significant differences existed for total beneficial bugs only at 7 days after application for both treatments containing Steward EC, which resulted in fewest total beneficial bugs (Table 30).

Table 27. Mean number of damsel bug nymphs (number/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

		Sample Date			
Insecticide and Rate/Acre		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.25a	7.50a	0.75a	8.50a
DiPel® DF	8 oz.	0.75a	12.25a	2.75a	5.50a
DiPel® DF + Steward®	8 oz. 3.2 oz.	0.00a	4.75a	1.50a	4.75a
Steward® EC	8 oz.	0.50a	3.50a	0.75a	4.00a
Zylo™	8 oz.	0.50a	10.50a	1.00a	7.75a
Untreated	-----	0.50a	4.75a	0.75a	8.00a
	P value	*0.64*	*0.26*	*0.32*	*0.28*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 28. Mean number of adult damsel bugs (numbers/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.00a	2.75a	2.00a	7.75a
DiPel®	8 oz.	0.25a	4.50a	1.50a	8.50a
DiPel® + Steward®	8 oz. 3.2 oz.	0.50a	3.25a	1.75a	6.00a
Steward® EC	8 oz.	0.50a	3.75a	1.75a	5.00a
Zylo™	8 oz.	0.50a	3.25a	1.75a	6.25a
Untreated	-----	0.00a	4.00a	1.50a	7.00a
	P value	*0.88*	*0.76*	*0.96*	*0.39*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 29. Mean total damsel bugs (numbers/10 sweeps) following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date			
		July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	0.25a	10.25a	2.75a	16.25a
DiPel®	8 oz.	1.00a	16.75a	4.25a	14.00a
DiPel® + Steward®	8 oz. 3.2 oz.	0.50a	8.00a	3.25a	10.75a
Steward® EC	8 oz.	1.00a	7.25a	2.50a	9.00a
Zylo™	8 oz.	1.00a	13.75a	2.75a	14.00a
Untreated	-----	0.50a	8.75a	2.25a	15.00a
	P value	*0.88*	*0.34*	*0.56*	*0.14*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Table 30. Mean total beneficial predacious bugs (*Orius*, big-eyed bugs, and damsel bugs) reported as number/10 sweeps following insecticide application on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Sample Date July 9	July 13	July 16	July 20
Coragen®	3.5 oz.	10.00a	43.00ab	43.25a	72.00a
DiPel®	8 oz.	13.75a	68.50a	50.0a	50.00a
DiPel® + Steward®	8 oz. 3.2 oz.	15.75a	32.25 b	40.5a	73.25a
Steward® EC	8 oz.	19.75a	37.25 b	34.75a	57.50a
Zylo™	8 oz.	14.75a	60.50ab	45.25a	74.25a
Untreated	-----	12.75a	55.25ab	49.25a	70.50a
	P value	*0.14*	*0.02*	*0.27*	*0.51*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Yields

One replicate was noted to have significantly less yield and significantly higher quality when statistical analyses were conducted. This necessitated a re-analyzation of data using only the three replicates that were not statistically different, which are contained in Tables 31-32.

Yields were not statistically different in this experiment (Table 31) even with the alfalfa butterfly caterpillar control noted early in this experiment (Table 4) or the later armyworm control later noted from most treatments. Highest yields were noted from the DiPel DF only treatment (1.74 tons/acre), which was 0.12 tons/acre more than untreated alfalfa (1.62 tons/acre).

Alfalfa treated with Zylo™ had a very similar mean yield as untreated alfalfa (Table 31). This was unexpected based on caterpillar control, however this treatment did result in highest numbers of *Empoasca* leafhoppers (Tables 14-16) and white-marked fleahoppers (Table 18) at various sample dates in this experiment. Feeding by *Empoasca* leafhoppers has long been noted to result in lower alfalfa yields (Kouskolekas and Decker, 1968).

It was not expected that the DiPel DF treatment would result in the highest yield, as this treatment provided little armyworm control when compared with untreated alfalfa (Table 13), although alfalfa butterfly caterpillars were controlled (Table 4).

One aspect of this chemistry that may have contributed to the higher numerical yield is the lack of additional chemistries (emulsifiable concentrate) accompanying this formulation. Low desert

alfalfa yields have been noted to have a significantly lower yield (0.1 tons/acre) when treated with emulsifiable concentrate formulations when compared with wettable formulations of the same pyrethroid insecticide active ingredient (Rethwisch et al., 2004). Lower alfalfa yields were also noted as rate of Steward and accompanying inert ingredients/acre increased, although insect control differences were negligible (Rethwisch et al., 2004).

Additional experimentation with the chemistries in this field trial is necessary to determine the consistency of the noted yield trends.

Quality

Relative Feed Value All insecticide treatments resulted in numerically higher relative feed value (RFV) than noted from untreated alfalfa (148.5). Zylo™ treated alfalfa had the highest RFV (159.3), however no statistical differences existed for RFV in this experiment (Table 31).

Net energy/Lactation (NE/Lact)

No statistical differences were noted for net energy/lactation. Highest NE-Lact was noted from Zylo™ treated alfalfa (0.673), followed by Coragen (0.666), while the lowest levels (0.65-0,653) were noted from alfalfa treated either of the two DiPel DF containing treatments (Table 31).

Percent Crude Protein

The highest percentages of crude protein were noted from treatments that contained Steward EC. Application of the 8 oz./acre rate of Steward EC resulted in significantly higher percent crude protein (17.0%) at the 90% dry matter level when compared with untreated (15.4%) or the DiPel DF only treated alfalfa (15.1%), with the DiPel DF + 3.2 oz./acre Steward EC treatment having the second highest crude protein level (15.93).

The Steward EC treatments had the fewest *Empoasca* leafhopper nymphs from 7-14 days post treatment (Table 14), and the 8 oz./acre treatment had numerically fewer total *Empoasca* leafhoppers than the combination treartment (Table 16).

Feeding by *Empoasca mexara* leafhoppers is known to result in a reduction of alfalfa protein in low desert alfalfa (Rethwisch and Tickes, 1987), however, leaf loss/feeding by armyworms is also thought to be involved, as the lowest mean percent crude protein levels were noted from the alfalfa treated with DiPel DF alone (15.1%) or untreated alfalfa (15.4%).

Acid detergent fiber

No statistical differences due to insecticide treatment was noted in this experiment for acid detergent fiber (ADF). Lowest ADF level (lower is better quality) was noted in alfalfa treated with Zylo (27.9) followed by Coragen (28.5). Mean ADF from all other treated and untreated alfalfa samples exceeded 29.3 (Table 32).

Table 31. Mean yields and quality of alfalfa at harvest on July 20 following insecticide application for alfalfa butterfly caterpillars on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		Tons/acre	RFV	NE/Lact	% Crude (90% dm)
Coragen®	3.5 oz.	1.71a	155.3a	0.666a	15.9ab
DiPel® DF	8 oz.	1.74a	148.9a	0.653a	15.1 b
DiPel® DF + Steward®	8 oz. 3.2 oz.	1.64a	147.9a	0.650a	15.9ab
Steward® EC	8 oz.	1.71a	151.5a	0.657a	17.0a
Zylo™	8 oz.	1.61a	159.3a	0.673a	15.6ab
Untreated	-----	1.62a	148.5a	0.657a	15.4 b
	P value	*0.94*	*0.57*	*0.52*	*0.02*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

Neutral detergent fiber

Neutral detergent fiber (NDF) was similar to that of ADF, with Zylo (34.2) and Coragen (34.7) having the lowest NDF, and all other treatments resulting in NDF above 35 (Table 32). Untreated alfalfa and the DiPel DF + Steward EC combination treatment both had the highest NDF level (35.8).

Total digestible nutrients

Total digestible nutrients (TDN) followed a similar pattern as ADF and NDF, but with Zylo (59.0) and Coragen (58.6) having the highest and therefore best TDN (Table 32). All other treatments resulted in a TDN between 57.6-57.9, very similar to untreated alfalfa (57.7).

Lignin

No statistical differences due to insecticide treatment was noted in this experiment (Table 32). Lowest lignin level was noted in alfalfa treated with Zylo (4.49%) followed by Coragen (4.62%), while the DiPel DF only treatment resulted in the highest mean percent lignin (5.26%).

Percent Fat

While no statistical differences for percentage of fat in harvested alfalfa hay due to insecticide treatment was noted (Table 32), a trend similar to that of percent protein was observed with highest level noted from alfalfa treated with the 8 oz./acre rate of Steward EC (1.19%) , and the lowest levels from the DiPel DF and untreated alfalfa (both 1.06%).

Table 32. Mean ADF, NDF, TDN, percent fat and lignin of alfalfa at harvest on July 20 following insecticide application for alfalfa butterfly caterpillars on July 6, 2018, Blythe, California.

Insecticide and Rate/Acre		ADF	NDF	TDN	Lignin	% Fat
Coragen®	3.5 oz.	28.5a	34.7a	58.6a	4.62a	1.14a
DiPel® DF	8 oz.	29.3a	35.4a	57.9a	5.26a	1.06a
DiPel® DF + Steward®	8 oz. 3.2 oz.	29.7a	35.8a	57.6a	4.69a	1.12a
Steward® EC	8 oz.	29.3a	35.1a	57.9a	4.99a	1.19a
Zylo™	8 oz.	27.9a	34.2a	59.0a	4.49a	1.15a
Untreated	-----	29.5a	35.8a	57.7a	4.89a	1.06a
	P value	*0.52*	*0.64*	*0.56*	*0.28*	*0.17*

Means in columns followed by the same letter are not statistically different at the 0.05 level of probability (Tukey's HSD test, JMP Pro 13).

- TDN reported at 100% dry matter, other quality parameters are reported at 90% dry matter.

LITERATURE CITED

Khan, H.A.A., and W. Akram. 2014. The effect of temperature on the toxicity of insecticides against *Musca domestica* L.: Implications for the effective management of diarrhea. PLoS ONE 9(4): e95636. https://doi.org/10.1371/journal.pone.0095636

Kouskolekas, C., and G.C. Decker. 1968. A Quantitative Evaluation of Factors Affecting Alfalfa Yield Reduction Caused by the Potato Leafhopper Attack. Journal of Economic Entomology. 61(4): 921–927.

Rethwisch, M.D., and B.R. Tickes. 1987. Effect of leafhopper feeding on alfalfa quality and yield. Pp. 105-108. In Proc 17th (1987) California Alfalfa Symposium. El Centro, CA. 162 pp.

Rethwisch, M.D,, M. Reay, l. Berger, E. Hawpe, J. Grudovich, R. Perez, and D. Ramos. 2004. Comparisons of insecticides for fall alfalfa insect populations, and resultant hay yields and quality. Pp. 1-17. IN Forage and Grain: A College of Agriculture and Life Sciences Report. Series P-140. University of Arizona. 72 pp. *cals.arizona.edu/pubs/crops/az1349*

Rethwisch, M.D., A. Grimm and M.T. Williams. 2007. Comparisons of Prism®, Trilogy®, Baythroid® XL, and Steward® for Control of Summer Alfalfa Insects. Pp. 1-8. In Forage and Grain: A College of Agriculture and Life Sciences Report, 2007 Series P-154. 107 pp. *https://repository.arizona.edu/handle/10150/203656*

Stern, V.M. and W. Bowen. 1963. Ecological studies of *Trichogramma semifumatum* with notes on *Apanteles medicaginis*, and their suppression of *Colias eurytheme* in southern California. Annals Ent. Soc. Am. 56: 358-372.

University of California Integrated Pest Management Program. 2017. UC IPM Pest Management Guidelines: Alfalfa - Alfalfa Caterpillar. UC ANR Publication 3430. *http://ipm.ucanr.edu/PMG/r1300611.html*