LABORATORY EVALUATION OF THE TOXICITY OF FOUR FUNGICIDES USED TO CONTROL *UNCINULA NECATOR* ON THE SPIDER MITE PREDATOR *METASEIULUS OCCIDENTALIS*

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ABSTRACT

Tetranychus pacificus McGregor is a major pest of vineyards whose population is successfully controlled by the naturally occurring mite predator *Metaseiulus occidentalis*. The occurrence of the pest outbreaks is hypothesized to be due to the predator being ill affected by chemical applications. The objectives of the work were to examine the amount of mortality that occurred in the predator due to the applications of the fungicides Rally® 40WSP, Quinoxyfen® 250SC, sulfur 92WP, and dusting sulfur. The fungicides Rally® 40WSP and Quinoxyfen® 250SC were found to not cause significant predator mortality, while applications of sulfur 92WP and dusting sulfur caused significant predator mortality at the 5% level. Based on previous experiments using sulfur compounds results showed little effect on the predators. Therefore, *M. occidentalis* raised at Sterling insectary are fairly resistant to Rally® 40WSP, Quinoxyfen® 250SC, sulfur 92WP, and dusting sulfur.

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Grape varieties grown in California for the production of wine and table grapes are highly susceptible to powdery mildew (*Uncinula necator*) (Dutcher and McGriffen, 1988). California grape growers commonly combat this fungus by applying preventive fungicides throughout the early season and erradicant fungicides once an infestation has become established. It is imperative that growers apply fungicides for this disease; left untreated, the fungus will usually affect both the amount and quality of the grapes that reach harvest.

Growers in the central valley that apply sulfur as a fungicide for powdery mildew throughout the growing season have witnessed the proliferation of the spider mite *Tetranychus pacificus* McGregor, a major pest of vineyards in the warm regions of the state. This spider mite has a rapid rate of reproduction, and at high density, can cause vines to drop the leaves it has fed on, leading to a decrease in the amount of photosynthetic area. The reduction of functional foliage affects the quality of the crop by leading to a loss in sugar production in the berries and delayed maturity.
A hypothesis as to why there is a surge in pest mite populations after sulfur applications is this element causes direct (death) or indirect (reduced fecundity) damage to the western predatory mite, *Metaseiulus occidentalis* (Nesbitt). This

predator occurs naturally in deciduous orchards and vineyards and if it is present at sufficient density *T. pacificus* normally do not reach devastating numbers. Most growers have multiple pests to combat and are dependent upon chemicals. The growers apply insecticides, fungicides, acaricides, and other materials to control their pest problems, which may adversely affect the predator-prey balance. A number of researchers has studied the effects of the materials mentioned previously on the western predatory mite so that growers will be more aware of the possibility of certain chemical applications causing harmful side effects.

I performed an experiment to follow up on these previous studies, in which I looked at the direct toxic effect of the fungicides Rally® 40WSP, Quinoxyfen® 250SC, sulfur 92WP, and dusting sulfur on the western predatory mite. The experiment was performed by the leaf spray method, which uses excised leaf discs to study the side effects of pesticides on predators. This method offers a fairly accurate replication of how these predators are affected by pesticides in field situations, and allows for the isolation and propagation of individuals that have survived the spray application.

Section II. Literature Review

Predator tolerance to pesticides is a rare trait. The mite family Phytoseiidae contains species of predatory mites that exhibit tolerances to chemical applications similar to that of their prey. A hypothesis of why the phytoseiid predators are capable of building up tolerance or resistance to chemicals is that the mite predators are exposed at all life stages to treated plant material, their migratory habitat is much reduced when compared to other winged natural enemies, and they are capable of a higher rate of spontaneous mutation than insects (Helle and Sabelis, 1985). This ability to evolve acquired tolerance plays a vital role in the development of safe spray programs for “resistance management” that will lessen the threat of spider mite pest resurgence and outbreaks post chemical applications.

History of Tolerance

The resistance to chemicals of the phytoseiid predator, *M. occidentalis,* has been demonstrated and documented for a long time. Tolerance of *M. occidentalis* to the organophosphate insecticide parathion was demonstrated in a California strawberry field (Huffaker and Kennett, 1953). *M. occidentalis* in apple orchards located in British Colombia were found to exhibit tolerance or possible resistance to parathion (Morgan and Anderson, 1958). *M. occidentalis* in Washington apple orchards that exhibited tolerance to several apple sprays, which included dinocap, azinphosmethyl, DDT, and parathion (Hoyt, 1969). All these early findings had one thing in common: the spider mite predator, *M. occidentalis*, exhibited an observable amount of tolerance to chemicals that had been sprayed heavily for some amount of time.

Pesticide Toxicity Studies

Fourteen strains of *M. occidentalis* collected from vineyards in the San Joaquin Valley were evaluated for resistance to the chemicals methomyl, dimethoate, and permethrin (Hoy et al., 1979). The predator strains were collected from vineyards in the California counties of Kern, Tulare, Fresno, and Madera. The study found that the vineyard predators were highly susceptible to methomyl, and had extremely low LC50 values (mean= 1.54 g of AI/ 100 l). Methomyl was observed to eradicate the predators, but due to the short residual life of the chemical, predator activity returned to the crop several weeks after the application. Vineyard predators were found to be highly susceptible to the chemical dimethoate (LC50 ranged from 10.9>116.4 g of AI/ 100 l). Resistance to the chemical permethrin, not registered for grape use, was non-existent (mean LC50= .28 g of AI/ 100 l). In conclusion, it was found that *M. occidentalis* in vineyards in the San Joaquin Valley are highly susceptible to applications of methomyl, dimethoate, and permethrin.

Hoy and Standow (1982) evaluated *M. occidentalis* for resistance to Cosan (micronized sulfur), FMC (wettable sulfur), THAT (flowable sulfur), lime sulfur (orthorix calcium polysulfides), and sulfur (dust). Predator strains were collected from three vineyards in the San Joaquin Valley, a pear orchard in Lake County, an apple orchard in Wenatchee Washington, wild blackberries in Berkeley, and an almond orchard in Turlock. The selected predator strain resistant to carbaryl-azinphosmethyl (a hybrid of orchard and vineyard strains) was also evaluated to determine if it demonstrated a resistance to sulfur (Roush and Hoy, 1981a). The lab experiment found that nymphs collected from vineyard strains were resistant to all formulations of sulfur, strains collected from orchards and wild blackberries were highly susceptible to sulfur, and the carbaryl-azinphosmethyl resistant strain showed moderate resistance to sulfur (Hoy and Standow, 1982). Sulfur was observed not to directly kill the adult predators, but to reduce their ability to increase and decrease their lifespan (Hoy and Standow, 1982). The study evaluated the mating compatibility of the resistant predators with susceptible predators, and found that when resistant females mated with susceptible males, shriveled eggs were produced (single pair cross R x S deposited 10 shriveled eggs)(Hoy and Standow, 1982). Therefore, due to the application of sulfur 8-20 times per season in vineyards for many years, the predators had overcome the indirect affects of sulfur, but in doing so their genetic makeup had begun to change, and a new biotype was being produced.

Hoy and Conley (1987) evaluated two colonies of *M. occidentalis* predators, a wild strain collected from an almond orchard in Stanislaus County and a mass-reared commercially available carbaryl-OP-sulfur-resistant strain, for susceptibility to sulfur 80WP. The predators were rated as having low toxicity if they were unaffected by one to five times field rate, moderate toxicity if 50% died at field rate, and high toxicity if 50% or more of the predators were killed at one-fourth and one-half of the field rate (Hoy and Conley, 1987). The study found that the toxicity of sulfur to the predator was high in the native strain and low to vineyard and COS strains (Hoy and Conley, 1987). Therefore the study found that strains that had a history of repeated usage of the element had an increased amount of resistance.

Alternate Prey

The feeding of *M. occidentalis* on alternate prey plays an extremely important role in the yearly maintenance of acceptable predator populations in the field. The alternate prey provides a food source for predators during extremely important periods in the predators' life cycle when the main prey is either present in very low numbers or absent. Some important alternate prey species of *M. occcidentalis* are *Eotetranychus willamettei* Ewing, *T. urticae* Koch, eriophyids, and several species of tydeids. The feeding on those species has been found by researchers to increase the predator effectiveness of ingesting, and controlling populations of *T. pacificus* during the season.

Flaherty and Huffaker (1970) studied the importance of tydeid mites in the control equation of *T. pacificus* by *M. occidentalis* in California vineyards. *M. occidentalis* was found to feed on the tydeids *Pronematus anconai* Baker and *P. ubiquitis* McGregor in late fall, providing enough food for the creation of a fairly large number of diapausing females. The following season, the predator populations in the areas with large amounts of tydeids from the previous fall prevented *T. pacificus* numbers from causing any economic damage.

Studies have shown alternate prey to be an important aspect in the control of *T. pacificus*. Not all cropping situations contain high amounts or varieties of this prey. Most species that serve as alternate food sources are extremely sensitive to chemicals, but some are capable of building up resistance. Croft and Jorgensen (1977) studied several species of phytophagous mites found in Utah and California apple orchards. The study found that unsprayed orchards contained a wide variety of tetranychid, tydeid, eriophyid, and other plant-feeding mites, while in sprayed orchards; the only mites present were *T. mcdanieli* and *A. schlechtendali*. Most agricultural crop growers are highly dependent upon chemical use in which leads to the availability of an extremely small variety of phytophagous mites for *M. occidentalis* to feed on.

In vineyard crops, tydeids in the *Pronematus* spp. are the most important and most commonly consumed alternate prey of *M. occidentalis*. In a laboratory setting, the predator was found to feed freely on those tydeids and reproduce extremely well (Flaherty and Huffaker, 1970).   Calvert and Huffaker evaluated for the effects of pollen (tydeids main food source) and sulfur applications on the mites *Pronematus* spp. and *M. occidentalis*. The experiment consisted of a plot with four applications of sulfur made between the end of April and early June, a plot that had ten sulfur applications made during frequent intervals from late April to mid-July, a plot with five monthly pollen applications from early April to early August, and a control plot that received neither sulfur nor pollen (Calvert and Huffaker, 1974). The frequency of sulfur applications used in the experiment matched the amount used in a commercial vineyard in the San Joaquin Valley.

The results of the study found that sulfur applications had a suppressive effect on populations of tydeids and *M. occidentalis*. Tydeids in both the control and pollen plots increased similarly in number during mid-June, while numbers in the four-treatment and ten-treatment sulfur plots increased two to seven weeks later (Calvert and Huffaker, 1974). Tydeid increases were the most suppressed in the 10 treatment sulfur plots, with only a mild increase until early August (when numbers rose dramatically), long after any suppressive effects of sulfur were evident (Calvert and Huffaker, 1974). The sulfur affected the predator population by delaying and diminishing the peak high of the treated plots. Predator populations in the control and pollen plots reached peak high in mid-August, while numbers did not peak in the sulfur treatments until early September (Calvert and Huffaker, 1974). The peak populations of the predators in the sulfur plots were much lower than the plots that did not receive sulfur, which may suggest that the suppressive effects of sulfur lingered longer on the predators.

The study found that applications of cattail pollen caused an increase in tydeid populations, and indirectly, an increase in predator populations. The tydeid population in the pollen plots, compared to the control and sulfur treatments, peaked earlier and reached a higher density in the late part of the season (pollen= 22.9/leaf (8/26), control= 7.6/leaf (9/7), 4-treatment= 11.5/leaf (8/26), 10-treatment= 16.2/leaf (9/7)) (Calvert and Huffaker, 1974). The most important time to have high numbers of tydeids is late in the season, since the main prey of the predator has already gone into diapause, and the predator populations are starting to produce diapause females, which need an available food source to survive. The highest counts of predators were found in the pollen plot, which was hypothesized to be indirectly due to that plot having the largest amount of prey (pollen= 1.9/leaf (8/21), control= 1.1/leaf (9/7), 4-10 treatment sulfur= .6/leaf (9/7)) (Calvert and Huffaker, 1974).

In conclusion, tydeids and *M. occidentalis* populations proliferated with pollen applications, and suffered with sulfur applications. The study also found that tydeids serve as a primary prey of *M. occidentalis* in the absence of other phytophagous mite species, and the maintenance of a predator-prey interaction throughout the year would improve the survival rate of overwintering female predators, which therefore would lead to a more successful control of pest mites the following season.

Section III. Materials and Methods

M. occidentalis used in the experiment came from the Sterling Insectary in Visalia, California. The predator at the insectary was reared on *Phaseolus vulgaris* L. (pinto beans), with *Tetranychus urticae* Koch (two-spotted spider mite) as prey. The experiment tested the susceptibility of the predator reared at the Sterling Insectary to the fungicides Rally® 40WSP (myclobutanil; A-butyl-a- (4-chlorophenyl)-1H-1, 2,4-triazole-1-propanenitrile), Quinoxyfen® 250SC (quinoline; 5,7-dichloro-4- (4-fluorophenoxy) quinoline), sulfur 92WP, and dusting sulfur. In addition to the fungicides, there was a control, which consisted of an application of de-ionized water. The fungicides were applied at these rates: Rally 40WSP 4oz/ 60 gal, Quinoxyfen 250SC 4floz/ 60 gal, sulfur 92W 4lb/ 100 gal, and dusting sulfur roughly at 50lb/ acre. The rate used for the dusting sulfur was inaccurate due the difficulty of applying such a small amount, but field dustings are often fairly uneven so the application simulated what may possibly happen.

Materials necessary for the experiment were 8X11 inch Rubbermaid® plastic tubs, a 2 centimeter cork cutter, excised leaf discs, two centimeters in diameter from ‘evolution’ rose plants, one-inch thick cotton quilt stuffing material saturated with de-ionized water, a fine camel hair paintbrush, a Crown Spra® spray tool, and a growth chamber.

The initiation of the experimental unit began with the tub. A layer of cotton, 1 to 2 inches thick, was saturated with de-ionized water and placed at the bottom of an 8X11 Rubbermaid® tub. Leaflets were then removed from the 'evolution' rose plant and cut into 2 centimeter diameter discs using a cork cutter. Ten leaf discs were cut, and placed on top of the saturated cotton with the lower surface of the leaf facing upwards. Once all the excised leaf discs were placed in the tub, about 20 *T. urticae* (mainly adults) were placed on the surface of each disc using a fine camel hair paintbrush. The prey were used to prevent predator starvation during the experiment. Once the discs were equipped with prey, five *M. occidentalis* predators (deutreronymph, protonymph or adults of both sexes) were brushed on each leaf disc using a fine camel hair paintbrush. The tub equipped with leaf discs covered with *T. urticae* and *M. occidentalis* was then placed under a fume hood and sprayed using the Crown Spra® spray tool for 10 seconds. The Crown Spra® spray tool was held 22 centimeters away from the leaf discs, and each side of the Rubbermaid rectangular tub was sprayed for five seconds, which roughly equaled a second per leaf disc. The dusting sulfur, which must be applied in dust form, was applied with a dusting applicator, which was held around 22 centimeters above the tub and lightly tapped three times over each disc. Once the fungicides were applied, the tub was immediately placed in a growth chamber for 48 hours. The growth chamber was set at 25˚C with a long day photoperiod of 14:10 hours. After 48 hours the tubs were removed and the leaf discs were examined with a dissecting microscope. If predator mobility was not observed, the fine camel hair paintbrush was used to encourage movement. Predators with obvious mobility and those initiating movement when prodded were labeled “live.” Predators that showed no movement or a minimal motion when prodded were considered “dead.” Predators that had just disappeared from the leaf disc were noted as “MIA”, and removed from the data when performing the statistical tests.

The design used was a completely randomized design. This design was chosen since all the surrounding conditions were controlled, and each of the experimental units were placed in identical situations. The experimental unit, which was the tub, was replicated four times per treatment. In the growth chambers, tubs from each treatment remained isolated from the tubs of the other treatments, thus lowering the likelihood of contamination.

The raw data, which included the number of individuals found live/dead, were analyzed using an analysis of variance. The ANOVA test found that at a 5% confidence level there was a difference in mortality between the treatments, so the information was further analyzed by mean separation using the Waller-Duncan Bayes LSD and multiple range test at a P= 0.05 (SAS Institute, 2001). The statistical test allows for the comparison of each treatment to the control and separation of significant differences.

Section IV. Results and Discussion

M. occidentalis was evaluated for susceptibility to the fungicide Rally® 40WSP. At an application rate of 4oz/ 60 gal the predator suffered a 11% mortality (Table 1). In comparing Rally® 40WSP treatments to the control, mortality was not significantly different at a 5% level with the means having a difference of only -0.0565 for mortality (Table2).

M. occidentalis was evaluated for susceptibility to the fungicide Quinoxyfen® 250SC. At an application rate of 4floz/ 60 gal the predator suffered a 12% mortality (Table 1). In comparing Quinoxyfen® 250SC treatments to the control treatments, mortality was not significantly different at a 5% level with the means having a difference of only -0.06809 for mortality (Table 2).

M. occidentalis was evaluated for susceptibility to the fungicide sulfur 92WP. Predator populations treated with wettable sulfur suffered 17% mortality at an application rate of 4lbs/ 100 gal (Table 1). Comparing wettable sulfur treatments to the control treatments, mortality was significantly different at a 5% confidence level with a difference in mean mortality of -0.1306 (Table 2).

M. occidentalis was evaluated for susceptibility to dusting sulfur. Dusting sulfur at an application rate of 50lbs/ acre caused a 21% mortality in the predator population (Table 1). Comparing dusting sulfur treatments to the control treatments, mortality was significant at a 5% level with the means having a difference of -0.17461 for mortality (Table 2).

Table 1. Survival of *M. occidentalis* after 48 hrs

Chemical	Total Treated[a]	% Mortality Raw Data
Control	157	5.64
Quinoxyfen® 250SC	160	12.12
Rally® 40WSP	169	11.12
Sulfur 92WP	144	16.89
Dusting Sulfur	177	21.08

[a]The total treated in actuality was 200 *M. occidentalis* per chemical, but not all were recovered after the 48 hr period so those numbers were removed from the statistical equation.

Table 2. Comparisons of treated *M. occidentalis* to the control

Treatment Comparisons		Difference Between Means	95% Confidence Limits		
Control	Dusting Sulfur	-0.17461	-0.26992	-0.07931	***
Control	Sulfur 92WP	-0.1306	-0.22714	-0.03406	***
Control	Quinoxyfen® 250SC	-0.06809	-0.1634	0.02722	
Control	Rally® 40WSP	-0.0565	-0.15181	0.03881	

*** Indicate comparison at the 0.05 level is significant

Applications of de-ionized water to *M. occidentalis* were statistically equivalent in terms of mortality as the applications of Rally® 40WSP and Quinoxyfen® 250SC. Neither Rally® 40WSP nor Quinoxyfen® 250SC significantly affected the predator; therefore, these chemicals should be considered extremely low in toxicity to the predator.

The predator was significantly affected by applications of sulfur 92WP when comparing that treatment to the control. Previous research that examined the affects of wettable sulfur on *M. occidentalis* has found that predator strains have a varying degree of tolerance. Research found that predator nymphs collected from vineyards were resistant to applications of sulfur 92WP (mean mortality= 29.5%, rate 552 g of AI/ 100 l)(Table 3)(Hoy and Standow, 1982). Adult predators from vineyards were also shown to have a high tolerance to applications of sulfur 80WP. This tolerance level, though not considered by all, was deemed high by Hoy and Conley (mortality >50%, rate 384 g of AI/ 100 l)(Table 3)(Hoy and Conley, 1987). Researchers that examined native predators found in fields with negligible spray histories of sulfur concluded that the predators were highly susceptible to the element. Predator larvae collected from wild blackberries were highly susceptible to sulfur 92WP (mortality= 90%, rate 552 g of AI/ 100 l)(Table 3)(Hoy and Standow, 1982). Predator adults from almond groves were highly susceptible to applications of sulfur 80WP (mortality= 100%, rate 384 g of AI/ 100 l)(Table 3)(Hoy and Conley, 1987). The genetically selected COS-resistant strain, selected for the possibility of mass production and release, was evaluated for tolerance to sulfur 80WP. The COS-resistant strain was found to be highly resistant to the wettable sulfur applications (mortality= 0%, rate 384 g of AI/ 100 l)(Table 3)(Hoy and Conley, 1987). In comparing the level of tolerance in the predator strain collected from Sterling insectary to that of previous research, the application rate I used fell in between the rates of the past experiments. The predators I examined did have a higher level of tolerance to wettable sulfur when compared to the susceptible native strains and a tolerance level that was almost equal to that of vineyard populations (mortality Sterling= 12%, rate 441 g of AI/ 100 l)(Table 3).   Thus, it can be inferred that *M.*

occidentalis from the Sterling insectary has a moderate to high level of resistance to sulfur 92W.

Table 3. Toxicity of wettable sulfur to *M. occidentalis*

Strain Source	Rate (g of AI/ 100 l)	Mortality
Fresno (vineyard) [1][α]	552	6%
Fresno (vineyard) [1][α]	552	53%
Alameda (wild blackberries) [1][α]	552	90%
Sterling Insectary[1][χ]	441	17%
Native in almonds[2][β]	384.34	100%
Vineyard[2][β]	384.34	0%
COS-resistant[2][β]	384.34	0%

[1] sources tested with sulfur 92WP
[2] sources tested with sulfur 80WP
α data from Hoy and Standow, 1982 publication
β data from Hoy and Conley, 1987 publication
χ data collected while completing this experiment

M. occidentalis was significantly affected by applications of dusting sulfur when comparing that treatment to the control. When comparing the mortality of the predators due to applications of sulfur it was only 21% more than that of the control applications. Previous research examining the direct effects of dusting sulfur on *M. occidentalis* had found that predator adults have a high level of tolerance and predator nymphs due not. Adult predators collected from vineyards, almonds, apples, blackberries, and the genetically selected COS-resistant strain exhibited no mortality due to dusting sulfur applications (mean mortality= 0%, rate 6.66 kg of AI/ acre)(Table 4)(Hoy and Standow, 1982). Nymph predators collected from vineyards, almonds, apples, blackberries, and the genetically selected COS-resistant strain had a varying degree of tolerance to applications of dusting sulfur. Nymphs examined from vineyards were shown to have a high level of resistance to applications of dusting sulfur (mean mortality= 17%, rate 6.66 kg of AI/ acre)(Table 4)(Hoy and Standow, 1982). Nymphs examined from almonds, apples, and wild blackberries were found to be susceptible to applications of dusting sulfur (mortality: almonds= 64%, apples= 96%, blackberries= 74%, rate 6.66 kg of AI/ acre)(Table 4)(Hoy and Standow, 1982). Nymphs of the genetically selected COS-resistant strain were examined to have a moderate tolerance to applications of dusting sulfur (mortality= 38%, rate of 6.66 kg of AI/ acre)(Table 4)(Hoy and Standow, 1982). In comparing the level of tolerance in the predator strain that I examined from Sterling insectary to that of previous research, the predator was found to have a tolerance buildup similar to that of the vineyard predators (mortality= 21%, rate 20 kg of AI/ acre)(Table 4). I assume that the tolerance to dusting sulfur found in the Sterling insectary strain is similar to that found in vineyard strains due to the low amount of mortality that occurred at an application rate that exceeded normal field application.

Table 4. Toxicity of dusting sulfur to *M. occidentalis*

Strain Source	Rate (g of AI/ 100 l)	Mortality	
		Adult	Nymph
Fresno (vineyard)	6.66 kg/acre	0%	0%
SJV (vineyard)	6.66 kg/acre	0%	32%
SJV (vineyard)	6.66 kg/acre	0%	20%
COS-resistant (vineyard/orchard)	6.66 kg/acre	0%	38%
Turlock (almond)	6.66 kg/acre	0%	64%
Washington (apple)	6.66 kg/acre	0%	96%
Alameda (wild blackberries)	6.66 kg/acre	0%	74%
Sterling Insectary	20kg/acre	21% (mixture)	

The recommended field rate is 40lbs/ acre, which applies 17.8kg of AI/ acre

Previous research on the toxicity of dusting sulfur to the predator had found that the element does not kill predatory mites, but affects them by other means. Dusting sulfur has been shown not to affect adult predators by killing them, but by slightly decreasing their life span and decreasing their ability to reproduce (Hoy and Standow, 1982). Adult female predators from vineyards were examined and proven resistant by exhibiting a very slight decrease in longevity and fecundity after applications of dusting sulfur (longevity (SD): control= 8.2 (3.8), sulfur treated= 7.5 (3.5); fecundity: control= 11.9± 7.7, sulfur treated= 10.6± 7.7)(Table 5)(Hoy and Standow, 1982). The COS-resistant strain, which had a moderate level of resistance to sulfur, had only a slight decrease in longevity and fecundity due to applications of dusting sulfur (longevity (SD): control= 7.1 (3.1), sulfur treated= 6.7 (3.2); fecundity: control= 13.4± 5.3, sulfur treated= 10.9± 5.7)(Table 5)(Hoy and Standow, 1982). The blackberry strain, which was susceptible to dusting sulfur, had a very slight decrease in longevity and fecundity (longevity (SD): control= 8.3 (3.0), sulfur treated= 6.9 (2.6); fecundity: control= 13.1± 6.7, sulfur treated= 11.0± 4.6)(Table 5)(Hoy and Standow, 1982). The almond strain, which was susceptible to dusting sulfur, had a significant decrease in longevity and fecundity to the applications (longevity (SD): control= 8.6 (2.9), sulfur treated= 5.5 (2.9); fecundity: control= 12.8± 5.4, sulfur treated= 7.1± 3.7)(Table 5)(Hoy and Standow, 1982). In the experiment I performed I did not examine the predator for a reduced life span or ability to increase. When counting the predators under the microscope after the 48-hour period, I did observe that only two leaf discs had mating individuals in the dusting sulfur treatment. Upon counting the predators sprayed with Rally® 40WSP, Quinoxyfen® 250SC, sulfur 92W, and de-ionized water, numerous predators per leaf disc were observed mating after the 48-hour period. This observation has leaded me to assume that the predator from Sterling insectary may not have appeared greatly affected by sulfur applications, but in actuality, was. Further research into those indirect effects would provide a more detailed explanation of the effects of dusting sulfur on the predator sold at the Sterling insectary.

Table 5. Indirect affects of Dusting Sulfur

	Longevity		Fecundity	
Strain	Control (SD)	Sulfur-Treated (SD)	Control	Sulfur-Treated
Raven	8.2 (3.8)	7.5 (3.5)	11.9+ 7.7	10.6+ 7.7
Sevin-Guthion	7.1 (3.1)	6.7 (3.2)	13.4+ 5.3	10.9+ 5.7
Turlock	8.6 (2.9)	5.5 (2.9) ***	12.8+ 5.4	7.1+ 3.7***
Berkley	8.3 (3.0)	6.9 (2.6)	13.1+ 6.7	11.0+ 4.6

***statisticaly significant at P< 0.05

I performed an experiment that evaluated the mortality effects of the chemicals Rally® 40WSP, Quinoxyfen® 250SC, sulfur 92WP, and dusting sulfur applied at a single rate to *M. occidentalis*. To provide a more accurate description of the toxicity of these chemicals to the predator, it would be necessary to continue the study using higher chemical doses along with different temperatures. The LC50 value of the Sterling Insectary *M. occidentalis* remains unknown for the chemicals evaluated, therefore this study provides very little information, if any, to a grower employing the chemicals at a rate higher than the single rate that I tested. The experiment I performed did not look into the possibility of the chemicals causing indirect harmful effects to the predator. Previous research has shown sulfur

applications to affect the predators in multiple indirect ways. It is possible that the other chemicals tested, along with sulfur, may have caused adverse affects, such as a decreased lifespan, decreased virosity, reduced fecundity, or reduced egg survival-but that remains unknown. In summary, the research remains a work in progress due to the fact that additional factors that could have an affect on the predator were not evaluated.

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