ENCAPSULATED MALATHION FOR BOLL WEEVIL: FIELD COMPARISONS OF SELECTED DOSES OF THREE AERIALLY APPLIED FORMULATIONS OF MALATHION IN NEW MEXICO

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Abstract

Three formulations of malathion, were each aerially applied at three different doses to cotton fields near Carlsbad New Mexico for evaluation against boll weevil. An extensive bioassay utilizing field collected cotton leaves and laboratory reared weevils and field estimates of feeding and oviposition damage were used to compare the individual activity levels among the different treatments. Mortalities resulting from weevils exposed to treated and untreated leaves were compared. Feeding and oviposition damage was compared between treated and untreated plots. Mortality data resulting from all treatments for residual ages of 0, 2, 4, 6, 8, 10, 12 and 14 days are shown. Feeding and oviposition damage data are reported generally for all treatments at 4 and 8 days after application.

All three doses of the standard Fyfanon ULV formulation demonstrated significant activity for two days after treatment. The traditional 0.93 lb AI/acre dose produced 100% mortality compared to 7% mortality in untreated populations on day 0. At 4 days after treatment, the 0.93 lb AI/acre dose produced 25% mortality compared to 11% in the untreated populations which was not statistically different in this study.

The two highest doses of the Cheminova CS formulation produced significant activity for 4 days after treatment. The 0.93 lb AI/acre dose produced 85% mortality compared to 48% mortality in untreated populations on day 4. At 6 days after treatment, both the 0.93 lb AI/acre dose and untreated populations demonstrated 11% mortality.

All three doses of the 3M MEC formulation demonstrated significant activity for 14 days after treatment. At 14 days after treatment, the 0.93 lb AI/acre, 0.77 lb AI/acre and 0.62 lb AI/acre doses produced 32%, 33% and 41% mortality respectively, compared to 6% mortality in the untreated population.

In this study, the 3M MEC formulation demonstrated significant activity for 12 days longer than the standard Fyfanon ULV treatment. When coupled with the data gathered in 1999, where the 0.77 lb AI/acre Cheminova CS formulation produced significant activity at 12 days after treatment, our data strongly suggest that activity for two weeks after treatment may be achieved with an encapsulated formulation of malathion. Such improvement in treatment effectiveness could substantially reduce overall pesticide load, application costs and logistics for boll weevil programs.

Introduction

The organized boll weevil eradication effort in the United States relies almost entirely on ground and aerial applications of ULV malathion as the control tool. Unfortunately, insecticide and application costs continue to increase. Traditional treatments of malathion are extremely effective against boll weevil but are only active for a few days after application. Eradication programs rely on intensive, carefully coordinated treatments concentrated over 1-3 seasons. In the early stages of the traditional program, malathion is applied repeatedly on a seven-day cycle in response to weevils captured in pheromone traps. Therefore, the insecticide and application costs associated with these treatments are extremely important to growers as they determine the economic feasibility of such efforts.

Repeating treatments with short durations of activity over large acreages also causes concerns for timely availability of both chemical and application equipment. Additionally, the total pesticide load per acre is substantially effected by such short cycles between treatments. These economical, logistical and environmental issues are magnified as the total acreage in the boll weevil eradication effort increases in the United States. From 1998 to 1999 active eradication acres increased from about 2.568 million to 6.813 million (personal communication, William Grefenstette, 1999). By 2000, active eradication acres had increased to 6.882 million and is predicted to increase by another 2.435 million acres in 2001 (personal communication, Osama El- Lissy, 2000). This increasing need of pesticide for boll weevil eradication efforts, although relatively short-term, makes the development of less expensive or longer lasting treatments extremely desirable.

Encapsulated formulations of the chemical of choice may be one way of reducing pesticide usage and thereby reducing both chemical and application costs. Because encapsulated formulations may last longer than traditional treatments and therefore may require less total seasonal AI/acre for acceptable results, their development is highly desirable.

Increased residual activity of a Cheminova encapsulated formulation of malathion was demonstrated initially on grasshoppers in 1995 (Foster and Reuter – unpublished data). In a later bioassay on a boll weevil surrogate (thurberia weevil) with a Cheminova formulation of encapsulated malathion, paper substrates sprayed in the laboratory using an apparatus designed to simulate aerial application and aged outside for selected periods of time in the late April Arizona sun produced exciting results (Foster et al. 1997). Substrates sprayed with the encapsulated formulation produced 100% mortality after exposure for 14 days while the standard malathion only produced 60% mortality after exposure for 3 days. A subsequent residual bioassay conducted during the winter with cotton leaves and the surrogate weevil proved inconclusive; probably due to the lower outdoor temperatures experienced during the study (Reuter et al. 1997). Temperatures during that second study were about 35 degrees lower than the initial study. However, two subsequent small plot field studies conducted in New Mexico with laboratory reared boll weevils and simulated aerial application, showed a trend of longer residual activity for the encapsulated formulation compared to the standard malathion (Reuter et al. 1998a - Report) (Reuter et al. 1998b – Report).

In an extensive bioassay using field collected cotton leaves which had been aerially sprayed, three doses of a Cheminova encapsulated malathion formulation demonstrated significantly longer activity against laboratory reared boll weevils when compared to equivalent doses of the standard malathion treatment, Fyfanon ULV (Foster et al. 2000). At 12 days after treatment, doses of the encapsulated formulation equivalent to 6 fl oz, 8 fl oz and 10 fl oz of the standard treatment resulted in 6%, 18% and 40% mortality to boll weevils respectively. This approximate doubling of mortality for each 2 fl oz equivalent increase suggests that a 12 fl oz equivalent dose of encapsulated malathion may result in ca. 80% mortality at 12 days after treatment which is numerically higher than the current standard 12 oz dose at 4 days after treatment (Foster et al. 2000).

If this level of activity is confirmed for that length of time, a doubling of the current interval between applications of malathion may be possible in the future. Such improvement in treatment effectiveness could dramatically

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reduce overall pesticide load, application costs and logistical difficulties for boll weevil control and eradication efforts dramatically.

In order to further examine the potential for encapsulated malathion against boll weevil, two different types of encapsulated formulations from different companies were assessed in the following study.

Materials and Methods

Study Site

The study was located in Eddy County of southeastern New Mexico approximately 5 miles northeast of the Carlsbad airport. The entire study utilized cotton fields provided by two growers. The general location and specific fields were selected because of the recent history of boll weevils and the existence of fields scheduled to receive no insecticide treatments. These plots were located in the same general area as those studied in 1999 (Foster et al. 2000). However, in 2000 they were located in different fields.

Ten square plots, 3.2 acres in size (375 ft. x 375 ft.) each located in separate fields were utilized for the study. This plot size accommodated 5 complete aerially applied spray swaths. Plots were of sufficient separation to ensure no contamination from study treatments or from any crop treatments to nearby fields. All study plots were planted to non-Bt upland cotton, Acala 1517. No insecticides other than those in the study were applied to the plots.

Treatments

Each of nine plots was sprayed with one of nine treatments (Table 1). The tenth plot was left untreated as a control. Assignment of treatments to plots was random. Three doses containing 0.93 lbs AI/acre, 0.77 lbs AI/acre and 0.62 lbs AI/acre of each of the three formulations were sprayed to separate plots. Depending on the individual eradication effort, the traditional program standards are 12 fl oz/acre (0.93 lb AI/acre) or 10 fl oz/acre (0.77 lb AI/acre). The Cheminova CS encapsulated formulation was aerially applied in total volumes of 26.86 fl oz/acre, 22.40 fl oz/acre and 17.92 fl oz/acre respectively on Aug. 3, 2000. The 3M MEC encapsulated formulation was aerially applied in total volumes of 71.18 fl oz/acre, 59.35 fl oz/acre and 47.51 fl oz/acre respectively on Aug. 4, 2000. The Cheminova and 3M rates are equivalent to 12 fl oz/acre, 10 fl oz/acre and 8 fl oz/acre, respectively of the currently used malathion standard, Fyfanon ULV. These respective doses of the Fyfanon ULV formulation were aerially applied on Aug. 5, 2000. While both encapsulated formulations may be mixed with water, all treatments in this study were applied undiluted.

All treatments were applied with a Cessna Ag Truck aircraft owned by the USDA, Animal and Plant Health Inspection Service (APHIS) and equipped with winglets (DBA–Ag Tips: Clack Oberholtzer, Alberta, Canada), (Fig. 1). Winglets are added to spray aircraft to reduce the production of fine droplets and to improve handling characteristics. The aircraft was operated by a USDA, APHIS pilot. The aircraft was equipped with a standard commercial spraying system, differentially corrected guidance and recording system and was operated at 5-10 ft (boom height) above plant canopy during applications. Ground personnel also provided guidance and ensured treatments occurred only during acceptable operating parameters. The aircraft and spraying system were calibrated for a 75 feet wide swath for all treatments. Prior to application, the aircraft spray system was calibrated to operate under parameters that resulted in delivery of spray within one percent of the desired rate per acre, for each of the nine treatments. Calibration was accomplished for each of the treatments by collecting and measuring the amount of material sprayed through each nozzle for each treatment set up, for a predetermined amount of time, and making adjustments in pressure until the desired output was achieved.

All treatments were applied through Flat Fan, Tee Jet stainless steel nozzle tips oriented straight down (Table 1).Cheminova CS encapsulated treatments, 0.93 lbs AI/acre, 0.77 lbs AI/acre and 0.62 lbs AI/acre, were applied at 120 mph and 44 psi, 42 psi and 39 psi respectively through 14, 12 and 10 (8003 size) tips respectively. The equivalent 3M MEC encapsulated treatments were applied at 120 mph and 50 psi through 24, 20 and 16 (8004 size) tips respectively. The equivalent Fyfanon ULV treatments were applied at 125 mph and 40psi, 44psi and 48 psi through 10, 8 and 6 (8002 size) tips respectively.

Winds during application were less than 2.5 mph for all plots except for one plot where winds were recorded ranging from 1.5 to 4 mph. Ground temperatures never exceeded air temperatures during application. Wind and other conditions recorded during application are summarized in Table 1.

Bioassay

A bioassay utilizing cotton leaves and laboratory reared boll weevils was used to assess each of the treatments. The design provided that each of the 10 treatments, including the untreated check, consisted of 10 replicates each containing 10 test insects for each of 8 selected intervals of evaluation. Therefore, 800 weevils were used for each treatment. Cotton leaves from the canopy level in the center swaths, near the center of each plot, in two lines separated by 30 ft, situated perpendicular to the flight path were collected at 0, 2, 4, 6, 8, 10, 12 and 14 days after application. Single leaves were collected every 5 rows along each of the 2 lines. Twenty leaves were collected from each plot including the untreated check plot on each post treatment interval. Twenty cages (100 mm x 15 mm plastic petri dishes modified with a screen-covered 45 mm opening on the top for ventilation) were established for each treatment on each selected post treatment interval. Each dish was stocked with 1 leaf and 5 active adult laboratory reared boll weevils. Each leaf stem was fitted with a vial containing water to prolong its turgor. Weevils were furnished by the USDA, APHIS, PPQ, Mission Plant Protection Center, Boll Weevil Rearing Facility at Mission Texas. Leaves collected in each plot were placed in zip lock plastic bags and transported to the laboratory to prevent contamination. Hands were thoroughly washed before entry into each plot and between different treatment set-ups in the laboratory. Dishes were maintained under normal day lengths for that time of the year at about 80° F in the New Mexico State University Laboratory near Artesia, New Mexico. Mortality was recorded daily for 7 days after weevils were exposed to leaves in petri dishes. Weevils were categorized as dead when no movement of any kind could be detected. Weevils were also categorized as seriously effected when there was detectable movement but obvious eminent death. These weevils were judged incapable of causing damage by feeding, mating or oviposition. Such weevils were considered functionally dead and were combined with physically dead individuals for analysis.

Field Damage

Field damage resulting from the remaining population after treatment was evaluated by collecting 1/3 developed squares and examining for feeding and/or oviposition damage. To insure that the damage had occurred very recently, squares were not collected if they showed obvious signs of damage (flaring, yellowing) in the field. Fifty squares were collected from each of four quadrants in each of the treated fields. Similarly, fifty squares were also collected from each of 4 additional control plots which were interspersed between treated plots, but at least 150 feet from treated areas. Collected squares were microscopically examined in the laboratory to determine levels of boll weevil feeding and oviposition. Squares were dissected when there was any doubt about the nature of the damage.

Droplet Deposition

White oil sensitive spray cards (Ciba-Geigy 52x72mm) and Black Kromekote oil sensitive spray cards (Henry Paper Company) cut to ca. the same size were stapled to leaves in the cotton canopy to obtain a general estimate of the density of spray droplets deposited for each treatment. White cards were used for the Fyfanon ULV formulation and black cards were used for both the CS and MEC formulations. Three lines each containing 10 cards situated perpendicular to the line of flight were located in the center of each plot. Lines of cards were separated from each other by ca. 30 feet. Cards within each line were separated by a distance equal to 5 rows of cotton. This design allowed for droplet sampling to cover ca. 2

swaths. Cards were placed immediately prior to application and were collected shortly after application and returned to the laboratory for analysis. Using a template, five, 1 cm^2 areas on each card were examined under a microscope at 8x magnification to determine the density of droplets deposited.

Analysis

Bioassay data were expressed as percent mortality based on the pretreatment population. A one-way analysis of variance was conducted with the Tukey multiple comparison test (Systat® 6.0, 1996) used to separate means. Results from the analysis with the observed data are presented. Further analysis was conducted when percentage mortality values were adjusted with the appropriate untreated check mortality to arrive at percentage control data (Connin and Kuitert 1952). The resulting means were then converted to ranks and compared as before. Differences in levels of damaged squares between treated and untreated plots were determined by t-tests (SAS- JMP 1998).

Results

Bioassay

The mean percentage mortality of boll weevils exposed to residual treatments of 0-14 days for each of the 9 treatments and the untreated control populations are shown in Table 2. Adjusted mortality data that compensates for mortality occurring in the untreated check populations are shown in Table 3. In both tables, mortality is shown for the progressive exposure of weevils for 1 through 3 days. Generally, results and discussion will focus on mortality recorded on the third day of exposure to each of the residual treatments.

At three days after weevils were exposed to treatments of two day old residuals, all treatments produced mortalities statistically equivalent and greater than their corresponding untreated populations demonstrated; except, the two lower doses of Cheminova CS, 0.77 lb AI/acre and 0.62 lb AI/acre, Table 2. However, previous zero day residuals of two of the three doses of 3M MEC and all doses of the Cheminova CS formulations resulted in mortalities lagging significantly behind the mortality levels produced by Fyfanon ULV.

The Fyfanon ULV treatments lost significant activity between two and four days after treatment. With four day old residuals, there was no significant difference in mortality between the Fyfanon ULV treatments and the corresponding untreated population. However, all three doses of 3M MEC and Cheminova CS, which were statistically equivalent to each other, produced mortality significantly greater than the Fyfanon ULV standard, However the lowest CS dose, was not significantly different than its corresponding untreated control population.

Six day old residuals resulted in no significant differences in mortalities between all doses of the Fyfanon ULV and the Cheminova CS formulatuions and their corresponding untreated control populations. However, all three doses of 3M MEC which were statistically equivalent to each other, performed significantly better than their corresponding untreated control and all other treatments.

All three doses of 3M MEC continued to significantly outperform their corresponding untreated control and all other treatments through residuals 14 days of age. Generally, throughout the study, there was no statistical advantage between the three doses of any individual formulation for any age of residual.

Examination of data adjusted for natural mortality that occurred in the check demonstrated similar results (Table 3). These data reflect the actual level of mortality that was attributed to each of the treatments. As in the earlier analysis, Fyfanon ULV outperformed both encapsulated formulations on day 0. Both encapsulated formulations performed equally at day 0. At 2 days after weevils were exposed, both Fyfanon ULV and 3M MEC outperformed the Cheminova CS formulation. However, at 4 days after weevils were exposed, both encapsulated formulations were equivalent to each other and superior to the standard Fyfanon ULV formulation.

From 6 days through 12 days after weevils were exposed, the 3M MEC formulation resulted in numerically and usually statistically higher mortality than the Fyfanon ULV standard. In this analysis, adjusted mortalities were so low at 14 days after exposure that no significant differences were seen between any of the treatments or formulations.

The study long differences between the highest doses of each of the 3 formulations can more easily be seen in Figure 1. The study long differences between the average of the combined doses of each of the three formulations is depicted in Figure 2.

Field Damage

Four days after treatment, samples from plots with the highest dose (0.93 lb AI/acre) of each of the formulations showed significantly fewer boll weevil infested squares compared to control plots. The standard, Fyfanon ULV and 3M formulations also showed significantly fewer infested squares compared to control plots at a dose of 0.77 lb AI/acre. Eight days after application, samples produced no significant differences in number of infested squares between treated and untreated plots. Additionally, no significant differences in the number of squares with feeding damage were detected between treated and untreated plots at 4 and 8 days after treatment. Extreme caution should be exercised in the final interpretation of infested squares and feeding damage in this study because of the small plot size, general infestation of the adjacent area, relative short period of the study, the ease with which boll weevils could have moved into the plots after treatment, and the lack of true replication.

Droplet Deposition

The number of spray droplets deposited per cm^2 for all non-encapsulated treatments are shown in Table 4. The different treatments produced mean droplet/cm_2 values in dose rank order. The values ranged from 7.6 droplets/cm^2 for the 8 fluid oz /acre dose to 13.1 droplets/cm^2 for the 12 fluid oz/acre dose. Based on the 12 fl oz/acre dose, the droplets/cm^2 for the 8 fl oz/acre and 10 fl oz/acre treatments were respectively 1.8 % and 12.6 % less than expected.

Droplets of encapsulated formulations were difficult to analyze on the black Kromekote spray cards. However, many larger droplets were easily visible on treated cotton leaves in the field with the unaided eye.

Discussion

Dramatic differences were seen between this study and one conducted in 1999 (Foster et al. 2000) in the performance of both the Fyfanon ULV and particularly the Cheminova CS formulations. In 1999, the high dose of Fyfanon ULV showed significant activity through residues 4 days old and lost activity between 4 and 6 days after treatment. In comparison in 2000, the same dose of Fyfanon ULV was significantly active through residues 2 days old but lost activity between 2 and 4 days after treatment. In 1999 the two highest doses, 0.93 lb AI/acre and 0.77 lb AI/acre, of 4 day old residuals exposed to weevils for 3 days, resulted in mortality significantly greater then the untreated populations 57% and 30%. This compared to mortalities of 25% and 22% respectively in 2000, which were not significantly different than the untreated control. More dramatically, in 1999 the high dose (0.77 lb AI/acre) of Cheminova CS showed significant activity with residues 12 days old compared to significant residual activity for only 4 days in 2000. Even though the 2000 study included a dose higher than used in 1999, no apparent activity was seen at or beyond 4 days after treatment with any of the doses of Fyfanon ULV. The dose rank order of mortality within formulations was more evident in the 1999 study compared to the 2000 study. Additionally, droplet deposition data revealed only ca. half as many droplets were deposited in 2000 compared to 1999 for all three Fyfanon ULV treatments.

Several design differences were noted however, between the two studies. Weevils used in 1999 were furnished by the USDA, ARS Gast Boll Weevil Rearing Facility at Mississippi State University. Weevils used in the 2000 study were furnished by the USDA, APHIS Mission Plant Protection Center Boll Weevil Rearing Facility in Mission Texas. The Mississippi facility was discontinued in 1999 due to eradication efforts within the state and responsibility for the rearing of boll weevil was transferred to Mission, Texas. It was noted that weevils from the Mission facility were visibly and substantially larger than previously used weevils even though the genetic stock was identical. Unexplainably, natural mortality that occurred in the untreated control populations was much higher and occurred sooner in 2000 compared to 1999. In addition, the Cheminova CS material used in the 2000 study was judged much more viscous than that used in 1999. However, even with these differences, the 3M MEC formulation showed significant activity longer than was seen with the Cheminova CS formulation in 1999.

In 1999 the 0.77 lb AI dose of the CS formulation resulted in an adjusted mortality of 29% at 12 days after treatment (40% unadjusted mortality and 16% untreated check mortality). The same dose of 3M MEC in the 2000 study produced adjusted mortality values of 35% and 29% on 12 and 14 days after treatment respectively. In 1999, we suggested that an increase in the encapsulated dose from 0.77 lb AI/acre to 0.93 lb AI/acre may double the mortality seen at 12 days after treatment. In this 2000 study, the 0.93 lb AI dose of 3M MEC produced an adjusted mortality of 45% at 12 days after treatment, a 1.6 increase over the 1999 0.77 lb AI/acre CS encapsulated treatment and an 1.3 increase over the 2000 0.77 lb AI/acre 3M MEC treatment.

Conclusions

The results of this study indicate that a significant and substantial increase in residual activity of malathion can be achieved with an encapsulated formulation. At the 0.93 lb AI/ac dose, the 3M MEC encapsulated formulation of malathion demonstrated significant activity for 10 days longer than the equivalent Fyfanon ULV dose. This total activity period was 5 times longer than the period shown by the current standard in this study and three times longer than shown by the standard in the 1999 study. When coupled with the data gathered in 1999, where the 0.77 lb AI/acre Cheminova CS formulation produced significant activity at 12 days after treatment, our data strongly suggest that an encapsulated dose equivalent to the current 12 fl oz/ac of the Fyfanon ULV treatment may produce acceptable activity for ca. 2 weeks. Such improvement in treatment effectiveness could substantially reduce overall pesticide load, application costs and total program logistics for boll weevil control and eradication efforts.

Further studies should be conducted to determine the effect of selected water ratio mixes with both encapsulated formulations. Water mixes would improve the flowability of the CS formulation and produce greater coverage for both encapsulated formulations. To ensure consistent periods of residual activity will result from the encapsulated formulations of malathion, full field replicated studies should be conducted under program conditions.

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Table 1. Meteorological conditions recorded during the aerial application of selected treatments of malathion near Carlsbad, New Mexico, 2000.

Treat*	Date	Time		Wind (mph)/dir	Air° F	Soil° F
CS 0.93	8/3	Start	6:02am	2 - 2.5/SE	62	61
		End	6:05am	2.5/SE		
CS 0.77	8/3	Start	6:20am	1 - 1.5/SE		
		End	6:23am			
CS 0.62	8/3	Start	6:45am	< 1/SE	68	65
		End	6:49am			
MEC 0.93	8/4	Start	6:05am	<1/S	67	66
		End	6:08am			
MEC 0.77	8/4	Start	6:25am	<1/SW	69	
		End	6:28am			
MEC 0.62	8/4	Start	6:45am	<1/NW	69	67
		End	6:49am	<0.2/NW		
FY 0.93	8/5	Start	6:30am	1 - 2/SE	70	66
		End	6:33am	1 - 2/SE		
FY 0.77	8/5	Start	6:54am	1 - 1.5/SE		
		End	6:57am	<1/SE		
FY 0.62	8/5	Start	7:17am	1.5 - 2.5/E	76	71
		End	7:22am	3 - 4/E		71

*CS: Cheminova concentrated suspension, MEC: 3M microencapsulated, FY: Cheminova Fyfanon ULV and following numbers indicate pounds of active ingredient applied per acre.

Table 2. Mean percentage mortality of boll weevils after 1 to 3 days of exposure to 0 to 14 day old malathion treated cotton leaves.

Treatment	Days after exposure* 1		2		3	
0 day						
Fyfanon ULV 0.93lb	100	a	100	a	100	a
Fyfanon ULV 0.77lb	93	a	100	a	100	a
Fyfanon ULV 0.62lb	99	a	100	a	100	a
Fyfanon ULV - UTC	1	e	1	d	7	d
Cheminova CS 0.93lb	24	cd	59	bc	72	bc
Cheminova CS 0.77lb	23	cd	47	bc	63	c
Cheminova CS 0.62lb	10	de	39	c	57	c
Cheminova CS - UTC	0	e	0	d	1	d
3M MEC 0.93lb	40	bc	60	bc	75	bc
3M MEC 0.77lb	54	b	86	a	95	ab
3M MEC 0.62lb	51	b	63	b	71	c
3M MEC – UTC	0	e	12	d	12	d
2 day						
Fyfanon ULV 0.93lb	93	a	100	a	100	a
Fyfanon ULV 0.77lb	82	ab	96	ab	96	a
Fyfanon ULV 0.62lb	62	bc	75	cd	92	ab
Fyfanon ULV - UTC	13	ef	26	e	48	c
Cheminova CS 0.93lb	48	cd	79	bc	90	ab
Cheminova CS 0.77lb	34	de	58	d	74	b
Cheminova CS 0.62lb	33	de	57	d	76	b
Cheminova CS - UTC	1	f	1	f	7	d
3M MEC 0.93lb	85	ab	96	ab	99	a
3M MEC 0.77lb	92	a	99	ab	100	a
3M MEC 0.62lb	84	ab	98	ab	100	a
3M MEC – UTC	1	f	5	f	13	d
4 day						
Fyfanon ULV 0.93lb	7	de	22	de	25	cd
Fyfanon ULV 0.77lb	12	cde	19	de	22	cd
Fyfanon ULV 0.62lb	13	cde	21	de	30	cd
Fyfanon ULV - UTC	0	e	3	e	11	d
Cheminova CS 0.93lb	43	ab	64	a	85	a
Cheminova CS 0.77lb	51	a	72	a	80	a
Cheminova CS 0.62lb	21	bcde	36	bcd	61	ab
Cheminova CS - UTC	13	cde	26	cde	48	bc
3M MEC 0.93lb	33	abc	59	ab	75	ab
3M MEC 0.77lb	43	ab	69	a	76	a
3M MEC 0.62lb	24	bcd	50	abc	63	ab
3M MEC – UTC	1	de	4	e	5	d
6 day						
Fyfanon ULV 0.93lb	18	bc	25	b	32	bc
Fyfanon ULV 0.77lb	13	c	21	b	41	b
Fyfanon ULV 0.62lb	4	c	12	b	32	bc
Fyfanon ULV - UTC	3	c	11	b	25	bc
Cheminova CS 0.93lb	3	c	4	b	11	c
Cheminova CS 0.77lb	3	c	5	b	14	c
Cheminova CS 0.62lb	6	c	12	b	18	bc
Cheminova CS - UTC	0	c	3	b	11	c
3M MEC 0.93lb	41	a	61	a	76	a
3M MEC 0.77lb	38	ab	55	a	68	a
3M MEC 0.62lb	38	ab	56	a	78	a
3M MEC – UTC	0	c	2	b	14	c

Table 2, continued

Treatment	Days after exposure* 1		2		3	
8 day						
Fyfanon ULV 0.93lb	16	bc	49	b	63	b
Fyfanon ULV 0.77lb	18	bc	42	bc	61	b
Fyfanon ULV 0.62lb	19	bc	49	b	64	b
Fyfanon ULV - UTC	11	bc	30	bcd	46	bc
Cheminova CS 0.93lb	4	c	12	d	16	d
Cheminova CS 0.77lb	7	bc	18	d	32	cd
Cheminova CS 0.62lb	13	bc	19	cd	36	cd
Cheminova CS - UTC	3	c	11	d	25	cd
3M MEC 0.93lb	27	b	47	b	87	a
3M MEC 0.77lb	65	a	74	a	92	a
3M MEC 0.62lb	71	a	79	a	96	a
3M MEC – UTC	11	bc	20	cd	44	bc
10 day						
Fyfanon ULV 0.93lb	2	cd	3	d	9	fg
Fyfanon ULV 0.77lb	4	bcd	12	cd	17	fg
Fyfanon ULV 0.62lb	1	d	5	d	8	g
Fyfanon ULV - UTC	4	bcd	10	d	17	fg
Cheminova CS 0.93lb	14	bcd	38	bc	53	cde
Cheminova CS 0.77lb	25	bc	53	ab	80	ab
Cheminova CS 0.62lb	18	bcd	49	ab	75	abc
Cheminova CS - UTC	11	bcd	30	bcd	46	de
3M MEC 0.93lb	59	A	76	a	86	ab
3M MEC 0.77lb	53	a	76	a	89	a
3M MEC 0.62lb	26	b	43	b	62	bcd
3M MEC – UTC	15	bcd	28	bcd	34	ef
12 day						
Fyfanon ULV 0.93lb	1	a	3	c	12	d
Fyfanon ULV 0.77lb	1	a	4	c	17	cd
Fyfanon ULV 0.62lb	0	a	2	c	14	cd
Fyfanon ULV - UTC	0	a	1	c	5	d
Cheminova CS 0.93lb	11	a	17	abc	24	bcd
Cheminova CS 0.77lb	4	a	7	bc	13	d
Cheminova CS 0.62lb	4	a	9	abc	14	cd
Cheminova CS - UTC	4	a	10	abc	17	cd
3M MEC 0.93lb	9	a	24	ab	48	ab
3M MEC 0.77lb	6	a	25	ab	38	abc
3M MEC 0.62lb	6	a	27	a	51	a
3M MEC – UTC	1	a	2	c	5	d
14 day						
Fyfanon ULV 0.93lb	**		**		**	
Fyfanon ULV 0.77lb	**		**		**	
Fyfanon ULV 0.62lb	2	a	6	abc	23	abcd
Fyfanon ULV - UTC	0	a	3	bc	12	bcd
Cheminova CS 0.93lb	1	a	2	bc	30	abc
Cheminova CS 0.77lb	0	a	9	abc	22	abcd
Cheminova CS 0.62lb	0	a	3	bc	17	abcd
Cheminova CS - UTC	0	a	1	c	5	d
3M MEC 0.93lb	2	a	15	ab	32	ab
3M MEC 0.77lb	5	a	18	a	33	ab
3M MEC 0.62lb	4	a	13	abc	41	a
3M MEC – UTC	0	a	2	bc	6	cd

* Means in a column followed by the same letter are not significantly different ($P \leq 0.05$).

** These treatments (fields) likely contaminated.

Table 3. Mean percentage adjusted mortality of boll weevils after 1 to 3 days of exposure to 0 to 14 day old malathion treated leaves.

	Days after exposure*					
Treatment	**1**		**2**		**3**	
0 day						
Fyfanon ULV .93lb	99.0	a	99.0	a	98.9	a
Fyfanon ULV .77lb	90.7	a	99.0	a	98.9	a
Fyfanon ULV .62lb	98.0	a	99.0	a	98.9	a
Cheminova CS .93lb	24.2	cd	59.0	bc	71.4	bc
Cheminova CS .77lb	23.0	cd	47.0	c	62.5	bc
Cheminova CS .62lb	10.0	d	39.1	c	56.7	c
3M MEC .93lb	40.0	bc	54.5	bc	71.4	bc
3M MEC .77lb	54.3	b	83.6	b	93.4	b
3M MEC .62lb	51.4	b	57.4	bc	78.0	bc
2 day						
Fyfanon ULV .93lb	91.3	a	98.7	ab	98.1	ab
Fyfanon ULV .77lb	79.1	ab	93.4	ab	90.6	abc
Fyfanon ULV .62lb	57.2	bc	66.0	c	83.5	abc
Cheminova CS .93lb	47.5	c	77.7	bc	88.8	abc
Cheminova CS .77lb	33.3	c	57.6	c	71.8	c
Cheminova CS .62lb	32.3	c	56.5	c	73.9	bc
3M MEC .93lb	84.4	a	95.1	a	97.8	ab
3M MEC .77lb	91.2	a	98.0	a	98.9	a
3M MEC .62lb	83.5	a	97.1	a	98.9	a
4 day						
Fyfanon ULV .93lb	7.0	b	20.6	bc	15.7	c
Fyfanon ULV .77lb	12.0	b	16.5	c	12.4	c
Fyfanon ULV .62lb	13.0	ab	18.6	c	21.4	c
Cheminova CS .93lb	34.5	ab	51.2	ab	70.2	a
Cheminova CS .77lb	43.7	a	62.2	a	61.2	ab
Cheminova CS .62lb	9.2	b	12.2	c	25.0	bc
3M MEC .93lb	32.3	ab	57.2	a	73.6	a
3M MEC .77lb	42.7	a	67.5	a	74.3	a
3M MEC .62lb	23.2	ab	47.8	abc	61.0	ab
6 day						
Fyfanon ULV .93lb	15.5	bc	15.7	b	9.3	b
Fyfanon ULV .77lb	10.3	cd	12.4	b	22.7	b
Fyfanon ULV .62lb	1.0	d	1.1	b	9.3	b
Cheminova CS .93lb	3.0	cd	1.0	b	1.1	b
Cheminova CS .77lb	3.0	cd	2.1	b	13.5	b
Cheminova CS .62lb	6.1	cd	9.5	b	8.1	b
3M MEC .93lb	41.0	a	60.0	a	74.8	a
3M MEC .77lb	38.0	a	54.1	a	62.7	a
3M MEC .62lb	38.0	ab	55.0	a	74.3	a
8 day						
Fyfanon ULV .93lb	6.7	b	27.1	cd	31.5	b
Fyfanon ULV .77lb	7.9	b	17.1	cd	27.8	b
Fyfanon ULV .62lb	9.0	b	27.1	cd	33.3	b
Cheminova CS .93lb	1.0	b	1.1	d	-12.0	c
Cheminova CS .77lb	4.1	b	7.9	cd	9.3	bc
Cheminova CS .62lb	10.3	b	9.0	cd	14.7	bc
3M MEC .93lb	17.9	b	33.6	bc	75.9	a
3M MEC .77lb	60.4	a	67.2	ab	84.7	a
3M MEC .62lb	67.4	a	73.7	a	91.7	a

Table 3, continued

	Days after exposure*					
Treatment	**1**		**2**		**3**	
10 day						
Fyfanon ULV .93lb	-2.1	bc	-7.8	d	-9.6	d
Fyfanon ULV .77lb	0.0	bc	2.2	bcd	0.0	d
Fyfanon ULV .62lb	-3.1	c	-5.6	cd	-10.8	d
Cheminova CS .93lb	3.4	bc	11.4	bcd	13.0	cd
Cheminova CS .77lb	20.2	ab	32.9	ab	62.6	ab
Cheminova CS .62lb	7.9	bc	27.1	abc	53.5	ab
3M MEC .93lb	51.8	a	66.3	a	78.0	a
3M MEC .77lb	44.7	a	66.5	a	82.7	a
3M MEC .62lb	14.1	abc	20.8	bcd	42.3	bc
12 day						
Fyfanon ULV .93lb	1.0	ab	2.0	ab	7.4	c
Fyfanon ULV .77lb	1.0	ab	3.0	ab	12.6	bc
Fyfanon ULV .62lb	0.0	ab	1.0	ab	9.5	bc
Cheminova CS .93lb	7.3	ab	7.8	ab	8.4	bc
Cheminova CS .77lb	0.0	ab	-3.3	b	-4.8	c
Cheminova CS .62lb	0.0	b	-1.1	b	-3.6	c
3M MEC .93lb	8.1	a	22.5	a	45.3	a
3M MEC .77lb	5.1	ab	23.5	ab	34.7	ab
3M MEC .62lb	5.1	ab	25.5	a	48.4	a
14 day						
Fyfanon ULV .93lb	**		**		**	
Fyfanon ULV .77lb	**		**		**	
Fyfanon ULV .62lb	2.0	a	3.1	a	12.5	a
Cheminova CS .93lb	1.0	a	1.0	a	26.3	a
Cheminova CS .77lb	0.0	a	8.1	a	17.9	a
Cheminova CS .62lb	0.0	a	2.0	a	12.6	a
3M MEC .93lb	2.0	a	13.3	a	27.7	a
3M MEC .77lb	5.0	a	16.3	a	28.7	a
3M MEC .62lb	4.0	a	11.2	a	37.2	a

* Means in a column followed by the same letter are not significantly different ($P \leq 0.05$).

** These treatments (fields) likely contaminated.

Table 4. Mean number of spray droplets per cm^2 on oil sensitive spray cards from 3 aerially applied malathion boll weevil treatments. (Carlsbad, New Mexico, 2000)

Formulation	**Rate lb AI/acre**	**Tip size**	**No.**	**Droplets**	**Expected Droplets***
Fyfanon ULV	0.93	8002	(10)	13.1	
Fyfanon ULV	0.77	8002	(8)	10.7	10.9
Fyfanon ULV	0.62	8002	(6)	7.6	8.7

* Based on total droplets produced per cm^2 with Fyfanon ULV at 0.93lb AI/acre.

Figure 1. Cessna Ag Truck equipped with winglets used in aerial applications of selected formulations of malathion.

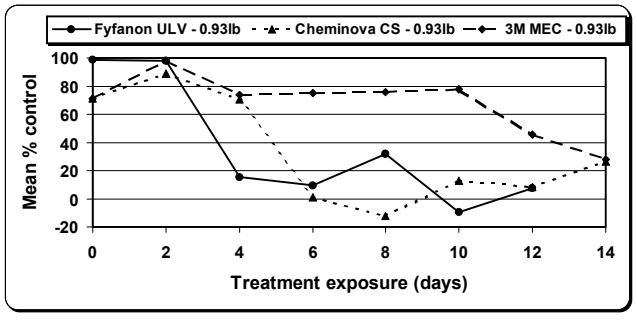

Figure 2. Mortality of boll weevils exposed for 3 days to selected ages of residue from the 0.93lb AI/acre dose of 3 formulations of malathion aerially applied to cotton leaves.

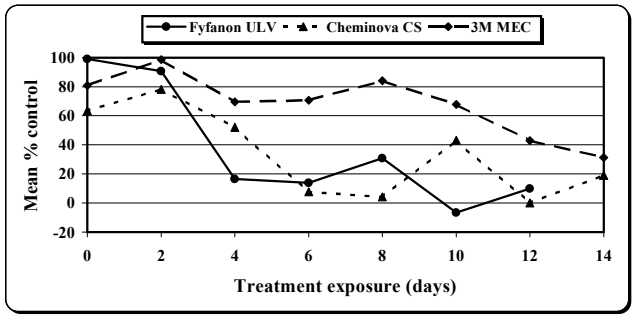

Figure 3. Average mortality of 3 combined doses (0.93, 0.77 and 0.62 lb AI/acre) of 3 formulations of malathion against boll weevil in aerially applied leaf bioassay.

Figure 4. Aerially applied encapsulated malathion droplets on cotton leaf.

Figure 5. Ventilated cages containing field collected, aerially treated cotton leaves and laboratory reared boll weevils used in bioassaying selected formulations and doses of malathion.