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EVALUATION OF SELECTED DOSES OF THREE FORMULATIONS OFAERIALLY APPLIED MALATHION FOR BOLL WEEVIL, *ANTHONOMUS GRANDIS* BOHEMAN

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Abstract

Two recently prepared formulations (Fyfanon ULV and Cheminova CS) and a one year old formulation (3M MEC) of malathion, were each aerially applied at three different doses to cotton fields near Tucumcari, New Mexico for evaluation against boll weevil. An extensive bioassay utilizing field collected cotton leaves and laboratory reared boll weevils was used to compare the individual activity levels among the different treatments. Mortalities resulting from weevils exposed to treated and untreated leaves were also compared. Mortality data resulting from all treatments for residual ages of 0, 2, 3, 4, 6, 8, 10, 12 and 14 days are shown.

Two doses of the standard Fyfanon ULV formulation demonstrated significant activity for 6 days after treatment. The traditional 0.93 lb AI/acre dose produced 100% mortality compared to 15% mortality in untreated populations on day 0. At 8 days after treatment, the 0.93 lb AI/acre dose produced 11% mortality compared to 9% in the untreated populations which was not statistically different in this study.

All three doses of the Cheminova CS formulation produced significant activity for 8 days after treatment. The 0.93 lb AI/acre dose produced significantly higher mortality compared to mortality in the untreated populations, 66% vs 38%, at 12 days after treatment. This significant residual activity lasted twice as long as that resulting from the standard Fyfanon ULV treatment.

All three doses of the one-year old 3M MEC formulation demonstrated significant activity for 8 days after treatment. At 8 days after treatment, the 0.93 lb AI/acre dose produced 37% mortality compared to 6% mortality in the untreated population. At 10 days after treatment the 0.93 lb AI/acre dose produced 27% mortality compared to 38% mortality in the untreated population.

Significant rainfall impacted residual treatment activity and confounded analysis of residues 8 to 14 days old. However, the recently prepared Cheminova CS formulation demonstrated significant activity at 12 days following treatment.

When coupled with data gathered in similar studies in 1999 and 2000, data from this study strongly suggest that activity for two weeks after treatment may be achieved with an encapsulated formulation of malathion. Such improvements 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 following application. Eradication programs rely on intensive, carefully coordinated treatments concentrated over 1-3 growing 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 affected 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 was predicted to increase by another 2.435 million acres in 2001 (El-Lissy and Grefenstette, 2001). In 2002 the acreage is predicted to increase an additional 740,000 acres to near a 10 million acre total (personal communication, Osama El-Lissy, 2001). 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.

The use of an encapsulated formulation may be one way of improving economical, logistical and environmental issues associated with the eradication effort. An encapsulated formulation of malathion with a longer period of activity would certainly improve treatment scheduling and associated logistics while reducing the number and cost of applications.

Earlier studies with a Cheminova formulation of malathion and a spray apparatus designed to simulate aerial application revealed exciting results in laboratory bioassays (Foster et al. 1997; Reuter et al. 1997) and field bioassays (Reuter et al. 1998a; Reuter et al.1998b). In a subsequent field study where different doses of the encapsulated malathion were applied aerially by aircraft to cotton plots, an extensive bioassay showed that 6 through 12 day old residuals of the high dose of the encapsulated malathion continued to perform statistically better than the equivalent dose of non-encapsulated malathion (Foster et al. 2000). In that study, 12 day-old residues of encapsulated malathion in increasing dose rank order (equivalent to 6, 8 and 10 fluid ozs of the standard), produced mortalities 1.5, 4.5 and 10 times greater than the 10 fluid ounce standard dose of Fyfanon ULV. That data suggests that a 12 fluid ounce equivalent dose of the encapsulated malathion may produce mortality at 12 days after treatment similar to mortality seen in that study at 4 days after treatment with the standard formulation.

In 2000, an additional formulation of encapsulated malathion (produced by 3M) was evaluated along with one-year old encapsulated malathion produced by Cheminova (Foster et al. 2001). In that study, the standard Fyfanon ULV formulation demonstrated significant activity for two days after treatment. The two highest doses of the one-year old Cheminova encapsulated formulation produced significant activity for 4 days after treatment while all three doses of the 3M formulation demonstrated significant activity for 14 days after treatment.

To further assess the potential of the 3M MEC formulation by evaluating one-year old material and to assess a modified Cheminova CS formulation (containing new stabilizing agents) for use against boll weevil, the following study was conducted.

Materials and Methods

Study Site

The study was located in Quay County of eastern New Mexico approximately 3 miles north and 2 miles west of the New Mexico State University, Agricultural Science Center near Tucumcari. The entire study utilized four cotton fields provided by a single grower, Robert Lopez. The general location and specific fields were selected because of the recent concern of boll weevils and the existence of fields scheduled to receive no insecticide treatments.

Ten square plots, each 3.2 acres in size (375 ft. x 375 ft.) and located no closer than 200 yards to other plots 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 other study treatments. All study plots were planted to non-Bt cotton, Paymaster 2156 RR and Paymaster 2145 RR. 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. 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 on 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) of Fyfanon ULV or Atrapa ULV. The Cheminova CS encapsulated formulation was aerially applied in total volumes of 26.20 fl oz/acre, 21.67 fl oz/acre and 17.45 fl oz/acre respectively on Aug. 1, 2001. The one year old 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. 3, 2001. The Cheminova and 3M rates are equivalent to 12 fl oz/acre, 10 fl oz/acre and 8 fl oz/acre, respectively of the commonly used malathion standard, Fyfanon ULV. These respective doses of the Fyfanon ULV formulation were aerially applied on Aug. 2, 2001. 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 (Table 1). 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. Cheminova CS encapsulated treatments, 0.93 lbs AI/acre, 0.77 lbs AI/acre and 0.62 lbs AI/acre, were applied at 120, 125, and 130 mph respectively at 36 psi 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 3 mph for all plots. 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 9 selected intervals of evaluation. Therefore, 900 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, 3, 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. Leaves collected in each plot were placed in zip lock plastic bags and transported to the laboratory to prevent contamination (Figure 2). Hands were thoroughly washed before entry into each plot and between different treatment set-ups in the laboratory. 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. Weevils were furnished by the USDA, APHIS, PPQ, Pest Detection , Diagnostic and Management Laboratory, Boll Weevil Rearing Facility at Mission Texas. Dishes were maintained under 14:10 (L:D) day lengths at about 80° F in the New Mexico State University Laboratory at Tucumcari , New Mexico (Figure 3). Mortality was recorded daily for 5 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.

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 on the rank transformation (Conover and Iman, 1981) of data and the Tukey multiple comparison test (Systat® 6.0, 1996) was used to separate means. 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.

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. Unfortunately, significant rain occurred during the last four intervals of the study, which has confounded analysis. These amounts of rainfall are shown in the footnotes of Table 2. Values in bold in tables 2 and 3 indicate when significant rainfall was associated with this data.

At three days after weevils were exposed to treatments of six-day old residuals, all doses within each formulation produced mortalities statistically equivalent (except for the 0.77 dose of Fyfanon ULV) and greater than the corresponding untreated populations, Table 2. Zero day residuals of 3M treatments resulted in mortalities lagging significantly behind the mortality levels produced by Fyfanon ULV (Table 3). A slight (numerical but not statistical) lag in mortalities of zero day residuals of all CS treatments compared to Fyfanon ULV treatments was also seen.

The standard Fyfanon ULV treatment lost activity between 6 and 8 days after treatment (Table 2). This coincided with the first significant rainfall recorded during this study. At 6 days after treatment the standard treatment produced significantly higher mortality (68%) compared to that seen in the untreated population (6%). With 8 day old residuals there was no significant difference in mortalities between the Fyfanon ULV treatments and the corresponding untreated population**.** Unexpectedly, the high dose of Fyfanon ULV indicated significant control with 10 and 12 day old residuals compared to its corresponding untreated population. However, during this time, other insecticide treatments were occurring on nearby melon plots and contamination of this plot was possible.

At eight days after treatment. all three doses of 3M MEC and Cheminova CS, which were statistically equivalent to each other, produced mortalities numerically greater than the Fyfanon ULV standard. Eight day old residuals of all treatments of both encapsulated formulations resulted in mortalities significantly greater than their corresponding untreated controls.

The highest dose of Cheminova CS continued to produce greater mortality than its corresponding untreated control with residuals 12 days old. The mortality level achieved with 12 day old residuals of the high dose of Cheminova CS was similar to that produced by the standard high dose of Fyfanon ULV with 6 day old residuals, 66% and 68% respectively. While there was generally little statistical advantage between doses of each encapsulated formulations, an advantage with the high dose was evident in the Fyfanon ULV treatments. All doses of all formulations tended to perform in dose rank order.

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 and Cheminova CS outperformed the MEC 3M encapsulated formulations on day 0. The highest dose of all three formulations performed equally through six-day old residuals. As indicated earlier, significant rain which occurred on 8/9 through 8/11 and again on 8/13 and 8/17 confounded results shown for the last four time intervals. However, the highest adjusted mortality produced during this period (46%) was produced by the high dose of Cheminova CS with a residual age of 12 days. In this analysis, adjusted mortalities were so low with 14 day old residuals 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 generally be seen in Figure 4. The study-long differences between the average of the combined doses of each of the three formulations is depicted in Figure 5.

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 7.9 droplets/cm^2 for the 8 fluid oz /acre dose to 14.4 droplets/cm^2 for the 12 fluid oz/acre dose. Based on 2000 droplet studies (Foster et al. 2001) the droplets /cm^2 for the 8 fl oz/acre, and 10 fl oz/acre and 12 fl oz /acre treatments were respectively 9.9%, < 0.01%< and 3.9% higher in this study.

Even though examination occurred almost immediately after treatment, droplets of encapsulated formulations were again as in previous studies, 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

Several differences were seen in results between this study and two similar studies conducted in 1999 (Foster et al. 2000) and 2000 (Foster et al. 2001). The standard formulation of malathion, Fyfanon ULV, and the Cheminova CS encapsulated formulations were evaluated in all three years. However, in 2000 the CS formulation evaluated was one year old. The 3M MEC formulation was evaluated in 2000 and 2001. However, in 2001 the 3M formulation evaluated was one year old.

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 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 comparison, in this 2001 study, the same high dose of Fyfanon ULV was significantly active through residues 6 day old but lost activity between 6 and 8 days after treatment. The levels of mortality and associated untreated control mortality at 6 days after treatment for 1999, 2000 and 2001 are 16% vs 0%, 32% vs 14% and 68% vs 6%% respectively for weevils held 3 days. Corresponding significant activity lasted 4, 2 and 6 days respectively.

More dramatically, in 1999 the high dose (0.77 lb AI/acre) of Cheminova CS showed significant activity with residuals 12 days old compared to significant residual activity for only 4 days in 2000 with an even higher dose, 0.93 lb AI/acre. However, we stress that material evaluated in 2000 was one year old. In comparison, in this 2001 study, the CS formulation (0.93 lb AI/acre) demonstrated significant activity with 12 day old residuals even though significant rainfall had occurred before 12 days of aging had occurred. The levels of mortality and associated untreated control mortality at 12 days after treatment for 1999 and 2001 were 40% vs 16% and 66% vs 38% respectively.

In 2000, the 3M MEC formulation demonstrated significant activity with residuals 14 days old while in this 2001 study significant activity was demonstrated for 8 days. Remarkably in 2001, this material was one year old and was subjected to several days of significant rainfall that coincided with cessation of activity. One-year old Cheminova CS demonstrated activity for 4 days (Foster et al. 2001) while one-year old 3M MEC demonstrated activity for 8 days.

One design difference between the three studies is noteworthy. Weevils used in 1999 were furnished by the USDA, ARS Gast Boll Weevil Rearing Facility at Mississippi State University. Weevils used in the 2000 and 2001 studies were furnished by the USDA, APHIS, PPQ, Pest Detection, Diagnostic, and Management Laboratory, Boll Weevil Rearing Facility near Edinburg, 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 Edinburg, 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 and 2001compared to 1999. Mean untreated control population mortality after weevils were held three days was 4.4% (n=7), 22.3% (n=21) and 16.2% (n=27) for 1999, 2000 and 2001 studies respectively.

Conclusion

Even though untimely and significant rainfall impacted this study, the results indicate that a substantial increase in residual activity of malathion can be achieved with an encapsulated formulation. At the 0.93 lb AI /acre rate, the modified Cheminova CS formulation demonstrated activity for 2 times as long and 6 days longer than the equivalent standard Fyfanon ULV rate. These results supplement earlier similar studies where a lower dose of Cheminova CS formulation showed activity 2 times as long as the standard and lasted 12 days (Foster et al. 2000) and the 3M MEC showed activity 5 times as long as the standard and lasted 14 days (Foster et al. 2001). Coupled with results from 2000, the data also indicate that the 3M MEC formulation may demonstrate better activity than the original Cheminova CS formulation one year after preparation. However, activity of both encapsulated formulations can still be impacted by substantial rainfall.

When coupled with the two earlier studies, our data strongly suggest that an encapsulated dose equivalent to the current 12 fl oz/ac of Fyfanon ULV treatment may produce acceptable activity for ca. two 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.

Data from this study and the one conducted in 2000 indicate that investigations should be undertaken to determine the cause of unusually high mortality that was seen in the untreated control populations of laboratory reared boll weevils. Further studies should be conducted to identify the specific rain resistant characteristics of the encapsulated formulations. Additionally, full field replicated studies should be conducted under operational program conditions to ensure consistent periods of residual activity will result from aerial applications of encapsulated formulations of malathion.

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Table 1. Meteorological conditions recorded during the aerial application of selected treatments of malathion near Tucumcari, New Mexico, 2001.

Treatment*	Date	Time		Wind (mph)/dir	Air °F	Soil °F
Cheminova CS 0.93lb	8/1	Start	5:42 AM	0.5/N	71	68
		End	5:44 AM	0.5/N		
Cheminova CS 0.77lb	8/1	Start	5:57 AM	0-0.5/W		
		End	6:00 AM	0-0.5/W		
Cheminova CS 0.62lb	8/1	Start	6:13 AM	0-0.2/W		
		End	6:17 AM	0-0.2/W	75	71
Fyfanon ULV 0.93lb	8/2	Start	6:32 AM	1.5/S	72	72
		End	6:35 AM	0.5/S		
Fyfanon ULV 0.77lb	8/2	Start	6:45 AM	0-1.0/NW		
		End	6:49 AM	1.0/S		
Fyfanon ULV 0.62lb	8/2	Start	7:01 AM	1.5-2.5/S		
		End	7:04 AM	1.5-2.0/S	79	75
3M MEC 0.93lb	8/3	Start	5:46 AM	1.0-2.0/S	67	65
		End	5:49 AM	1.0-2.0/S		
3M MEC 0.77lb	8/3	Start	6:01 AM	2.5-3.0/S		
		End	6:05 AM	2.0-3.0/S		
3M MEC 0.62lb	8/3	Start	6:32 AM	0-1.0/SW		
		End	6:37 AM	1.0-1.5/SW	70	69

* Malathion formulations and 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, 2001.

	Days after exposure – mean % mortality*		
Treatment	**1**	**2**	**3**
0 day			
Fyfanon ULV 0.93lb	100 A	100 a	100 a
Fyfanon ULV 0.77lb	99 A	100 a	100 a
Fyfanon ULV 0.62lb	96 A	98 a	100 a
Fyfanon ULV - untreated	0 D	2 e	15 d
Cheminova CS 0.93lb	78 B	96 ab	98 a
Cheminova CS 0.77lb	68 Bc	90 bc	98 a
Cheminova CS 0.62lb	62 Bc	82 cd	94 ab
Cheminova CS - untreated	1 D	10 e	21 d
3M MEC 0.93lb	51 c	73 d	82 c
3M MEC 0.77lb	55 c	81 cd	93 abc
3M MEC 0.62lb	46 c	71 d	83 bc
3M MEC - untreated	2 d	12 e	30 d
2 day			
Fyfanon ULV 0.93lb	84 a	90 ab	94 abc
Fyfanon ULV 0.77lb	35 c	50 c	70 d
Fyfanon ULV 0.62lb	49 bc	67 bc	79 cd
Fyfanon ULV - untreated	5 d	12 d	23 e
Cheminova CS 0.93lb	62 abc	90 ab	98 a
Cheminova CS 0.77lb	40 c	73 abc	81 bcd
Cheminova CS 0.62lb	32 c	69 bc	79 d
Cheminova CS - untreated	2 d	12 d	30 e
3M MEC 0.93lb	80 ab	90 ab	97 abc
3M MEC 0.77lb	80 ab	91 a	97 abc
3M MEC 0.62lb	57 abc	76 abc	84 abcd
3M MEC - untreated	1 d	10 d	22 e
3 day			
Fyfanon ULV 0.93lb	77 a	87 ab	91 a
Fyfanon ULV 0.77lb	48 ab	58 bc	70 b
Fyfanon ULV 0.62lb	66 ab	78 abc	88 ab
Fyfanon ULV - untreated	1 d	10 e	22 c
Cheminova CS 0.93lb	57 ab	78 abc	86 ab
Cheminova CS 0.77lb	55 ab	74 abc	89 ab
Cheminova CS 0.62lb	35 bc	48 cd	65 b
Cheminova CS - untreated	5 cd	12 de	23 c
3M MEC 0.93lb	75 a	94 a	98 a
3M MEC 0.77lb	75 a	87 ab	94 a
3M MEC 0.62lb	61 ab	70 abc	78 ab
3M MEC - untreated	7 cd	14 de	16 c
4 day			
Fyfanon ULV 0.93lb	83 a	90 a	95 ab
Fyfanon ULV 0.77lb	52 b	61 b	66 c
Fyfanon ULV 0.62lb	51 b	62 ab	68 bc
Fyfanon ULV - untreated	7 c	14 c	16 d
Cheminova CS 0.93lb	65 ab	82 ab	96 ab
Cheminova CS 0.77lb	71 ab	85 ab	91 abc
Cheminova CS 0.62lb	56 ab	67 ab	81 bc
Cheminova CS - untreated	1 c	10 c	22 d
3M MEC 0.93lb	62 ab	87 ab	96 a
3M MEC 0.77lb	68 ab	87 ab	97 ab
3M MEC 0.62lb	52 b	74 ab	87 abc
3M MEC - untreated	3 c	7 c	18 d

6 day			
Fyfanon ULV 0.93lb	33 ab	50 bc	68 ab
Fyfanon ULV 0.77lb	9 cd	19 de	23 cd
Fyfanon ULV 0.62lb	22 bc	34 cd	51 bc
Fyfanon ULV - untreated	1 d	1 e	6 d
Cheminova CS 0.93lb	48 ab	64 ab	81 a
Cheminova CS 0.77lb	59 a	77 ab	84 a
Cheminova CS 0.62lb	37 ab	49 bc	69 ab
Cheminova CS - untreated	3 d	7 de	18 cd
3M MEC 0.93lb^{+}	**56 a**	**82 a**	**88 a**
3M MEC 0.77lb^{+}	**34 ab**	**65 ab**	**78 ab**
3M MEC 0.62lb^{+}	**23 bc**	**55 abc**	**73 ab**
3M MEC – untreated^{+}	**1 d**	**4 e**	**4 d**
8 day			
Fyfanon ULV 0.93lb^{++}	**3 bc**	**5 bc**	**11 bc**
Fyfanon ULV 0.77lb^{++}	**3 bc**	**6 bc**	**10 bc**
Fyfanon ULV 0.62lb^{++}	**4 bc**	**6 bc**	**10 bc**
Fyfanon ULV – untreated^{++}	**1 c**	**2 c**	**9 bc**
Cheminova CS 0.93lb^{+}	**10 abc**	**17 abc**	**25 ab**
Cheminova CS 0.77lb^{+}	**10 abc**	**22 abc**	**31 ab**
Cheminova CS 0.62lb^{+}	**24 a**	**45 a**	**50 a**
Cheminova CS – untreated^{+}	**1 c**	**4 bc**	**4 c**
3M MEC 0.93lb^{+++}	**15 ab**	**24 ab**	**37 a**
3M MEC 0.77lb^{+++}	**11 abc**	**26 ab**	**35 a**
3M MEC 0.62lb^{+++}	**8 abc**	**13 abc**	**24 ab**
3M MEC – untreated^{+++}	**0 c**	**4 bc**	**6 c**
10 day			
Fyfanon ULV 0.93lb	**4 a**	**21 a**	**38 a**
Fyfanon ULV 0.77lb	**2 a**	**7 abcd**	**22 abc**
Fyfanon ULV 0.62lb	**4 a**	**21 ab**	**36 a**
Fyfanon ULV - untreated	**3 a**	**6 bcd**	**12 bc**
Cheminova CS 0.93lb^{+++}	**7 a**	**10 abcd**	**17 abc**
Cheminova CS 0.77lb^{+++}	**1 a**	**3 d**	**9 bc**
Cheminova CS 0.62lb^{+++}	**2 a**	**4 d**	**12 bc**
Cheminova CS untreated^{+++}	**0 a**	**4 cd**	**6 c**
3M MEC 0.93lb	**6 a**	**22 abc**	**27 ab**
3M MEC 0.77lb	**6 a**	**9 abcd**	**16 abc**
3M MEC 0.62lb	**1 a**	**11 abcd**	**18 abc**
3M MEC - untreated	**8 a**	**24 ab**	**38 a**
12 day			
Fyfanon ULV 0.93lb	**11 a**	**22 ab**	**44 abc**
Fyfanon ULV 0.77lb	**2 bc**	**7 c**	**24 cdef**
Fyfanon ULV 0.62lb	**3 abc**	**5 c**	**24 cde**
Fyfanon ULV - untreated	**3 abc**	**9 bc**	**22 defg**
Cheminova CS 0.93lb	**16 a**	**49 a**	**66 a**
Cheminova CS 0.77lb	**11 ab**	**38 a**	**54 ab**
Cheminova CS 0.62lb	**9 ab**	**19 ab**	**36 bcd**
Cheminova CS - untreated	**8 abc**	**24 ab**	**38 bcd**
3M MEC 0.93lb	**1 bc**	**6 c**	**11 efgh**
3M MEC 0.77lb	**3 abc**	**5 c**	**7 fgh**
3M MEC 0.62lb	**1 bc**	**2 c**	**5 gh**
3M MEC - untreated	**0 c**	**0 c**	**2 h**

14 day			
Fyfanon ULV 0.93lb	**1 a**	**2 a**	**6 a**
Fyfanon ULV 0.77lb	**0 a**	**1 a**	**1 a**
Fyfanon ULV 0.62lb	**1 a**	**2 a**	**5 a**
Fyfanon ULV - untreated	**1 a**	**1 a**	**5 a**
Cheminova CS 0.93lb	**0 a**	**2 a**	**6 a**
Cheminova CS 0.77lb	**1 a**	**3 a**	**7 a**
Cheminova CS 0.62lb	**1 a**	**1 a**	**1 a**
Cheminova CS - untreated	**0 a**	**0 a**	**2 a**
3M MEC 0.93lb	**3 a**	**4 a**	**13 a**
3M MEC 0.77lb	**0 a**	**5 a**	**8 a**
3M MEC 0.62lb	**4 a**	**6 a**	**12 a**
3M MEC - untreated	**0 a**	**2 a**	**7 a**

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

+ These treatments received a total of 0.18 inches of rain prior to leaf sample collection.

++ These treatments received a total of 0.35 inches of rain prior to leaf sample collection.

+++ These treatments received a total of 1.18 inches of rain prior to leaf sample collection.

Bold values indicate significant rainfall occurred after application and before leaf collection.

Table 3. Mean percentage adjusted mortality of boll weevils after 1 to 3 days of exposure to 0 to 14 day old malathion-treated cotton leaves, 2001.

	Days after exposure – mean % mortality*		
Treatment	**1**	**2**	**3**
0 day			
Fyfanon ULV 0.93lb	100 a	100 a	100 a
Fyfanon ULV 0.77lb	99 a	100 a	100 a
Fyfanon ULV 0.62lb	96 a	98 a	100 a
Cheminova CS 0.93lb	78 b	95 a	97 a
Cheminova CS 0.77lb	68 bc	89 ab	97 a
Cheminova CS 0.62lb	60 bc	79 bc	92 a
3M MEC 0.93lb	50 c	69 bc	74 b
3M MEC 0.77lb	54 c	78 bc	90 ab
3M MEC 0.62lb	45 c	67 c	76 b
2 day			
Fyfanon ULV 0.93lb	82 a	89 ab	92 ab
Fyfanon ULV 0.77lb	33 c	43 c	60 c
Fyfanon ULV 0.62lb	45 bc	58 bc	73 abc
Cheminova CS 0.93lb	61 abc	89 ab	97 a
Cheminova CS 0.77lb	39 c	68 abc	75 abc
Cheminova CS 0.62lb	30 c	64 bc	70 bc
3M MEC 0.93lb	79 ab	88 ab	94 ab
3M MEC 0.77lb	80 ab	90 a	96 ab
3M MEC 0.62lb	57 abc	74 abc	83 abc
3 day			
Fyfanon ULV 0.93lb	77 a	86 ab	88 ab
Fyfanon ULV 0.77lb	47 ab	52 bc	61 bc
Fyfanon ULV 0.62lb	65 ab	74 abc	84 abc
Cheminova CS 0.93lb	54 ab	73 abc	84 abc
Cheminova CS 0.77lb	53 ab	69 abc	86 abc
Cheminova CS 0.62lb	31 b	40 c	54 c
3M MEC 0.93lb	74 a	93 a	96 a
3M MEC 0.77lb	73 a	85 abc	94 a
3M MEC 0.62lb	57 ab	64 abc	75 abc
4 day			
Fyfanon ULV 0.93lb	81 a	88 a	94 a
Fyfanon ULV 0.77lb	47 a	50 a	61 b
Fyfanon ULV 0.62lb	47 a	54 a	60 b
Cheminova CS 0.93lb	65 a	80 a	95 a
Cheminova CS 0.77lb	71 a	83 a	88 ab
Cheminova CS 0.62lb	55 a	64 a	73 ab
3M MEC 0.93lb	60 a	86 a	96 a
3M MEC 0.77lb	67 a	86 a	96 a
3M MEC 0.62lb	50 a	72 a	85 ab
6 day			
Fyfanon ULV 0.93lb	32 abc	49 abcd	66 ab
Fyfanon ULV 0.77lb	8 c	18 d	18 c
Fyfanon ULV 0.62lb	21 bc	34 cd	48 bc
Cheminova CS 0.93lb	46 ab	62 abc	76 ab
Cheminova CS 0.77lb	58 a	75 ab	83 a
Cheminova CS 0.62lb	34 ab	45 bcd	66 ab
3M MEC 0.93lb	56 a	80 **a**	**87 a**
3M MEC 0.77lb	33 abc	63 **ab**	**76 ab**
3M MEC 0.62lb	22 bc	52 **abcd**	**72 ab**

8 day			
Fyfanon ULV 0.93lb	2 b	3 **b**	**2 cd**
Fyfanon ULV 0.77lb	2 b	4 **b**	**1 d**
Fyfanon ULV 0.62lb	3 b	4 **b**	**1 d**
Cheminova CS 0.93lb	9 ab	13 **ab**	**22 abcd**
Cheminova CS 0.77lb	9 ab	17 **ab**	**28 abc**
Cheminova CS 0.62lb	23 a	43 **a**	**47 a**
3M MEC 0.93lb	15 ab	20 **ab**	**34 ab**
3M MEC 0.77lb	11 ab	23 **ab**	**31 ab**
3M MEC 0.62lb	8 ab	9 **ab**	**19 bcd**
10 day			
Fyfanon ULV 0.93lb	0 ab	14 **a**	**30 a**
Fyfanon ULV 0.77lb	-2 ab	-1 **ab**	**11 ab**
Fyfanon ULV 0.62lb	1 ab	16 **a**	**27 a**
Cheminova CS 0.93lb	7 a	6 **ab**	**6 ab**
Cheminova CS 0.77lb	1 ab	-1 **ab**	**-3 b**
Cheminova CS 0.62lb	2 ab	0 **ab**	**1 ab**
3M MEC 0.93lb	-3 ab	-7 **ab**	**-15 bc**
3M MEC 0.77lb	-4 ab	-29 **b**	**-36 c**
3M MEC 0.62lb	-9 b	-24 **b**	**-32 c**
12 day			
Fyfanon ULV 0.93lb	8 a	10 **ab**	**28 ab**
Fyfanon ULV 0.77lb	-1 a	-7 **b**	**3 bc**
Fyfanon ULV 0.62lb	0 a	-9 **b**	**3 bc**
Cheminova CS 0.93lb	7 a	28 **a**	**46 a**
Cheminova CS 0.77lb	2 a	11 **ab**	**26 abc**
Cheminova CS 0.62lb	-1 a	-13 **b**	**-3 c**
3M MEC 0.93lb	1 a	6 **ab**	**9 bc**
3M MEC 0.77lb	3 a	5 **ab**	**15 bc**
3M MEC 0.62lb	1 a	2 **ab**	**3 bc**
14 day			
Fyfanon ULV 0.93lb	0 a	1 **a**	**1 a**
Fyfanon ULV 0.77lb	-1 a	0 **a**	**-4 a**
Fyfanon ULV 0.62lb	0 a	1 **a**	**0 a**
Cheminova CS 0.93lb	0 a	2 **a**	**4 a**
Cheminova CS 0.77lb	0 a	3 **a**	**5 a**
Cheminova CS 0.62lb	1 a	1 **a**	**-1 a**
3M MEC 0.93lb	3 a	2 **a**	**7 a**
3M MEC 0.77lb	0 a	3 **a**	**1 a**
3M MEC 0.62lb	4 a	4 **a**	**6 a**

* The data was corrected for natural mortality. Numbers in a column followed by the same letter are not significantly different ($P \leq 0.05$).
Bold values indicate significant rainfall occurred after treatment and before leaf collection.

Table 4. Mean number of spray droplets per cm^2 on oil sensitive spray cards from 3 aerially applied malathion boll weevil treatments (Tucumcari, New Mexico, 2001).

Formulation	Rate b AI/acre	Tip size	No. tips	Droplets	2000 study*
Fyfanon ULV	0.93	8002	10	14.4	13.1
Fyfanon ULV	0.77	8002	8	10.8	10.7
Fyfanon ULV	0.62	8002	6	7.9	7.6

* Droplets produced for identical treatments applied in 2000 Carlsbad, New Mexico study.

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

Figure 2. Sampling technique used in collection of aerially treated (and untreated) cotton leaves for use in laboratory bioassays.

Figure 3. Ventilated cages containing field collected, aerially treated cotton leaves and laboratory reared boll weevils used in bioassaying selected formulations and doses of malathion.

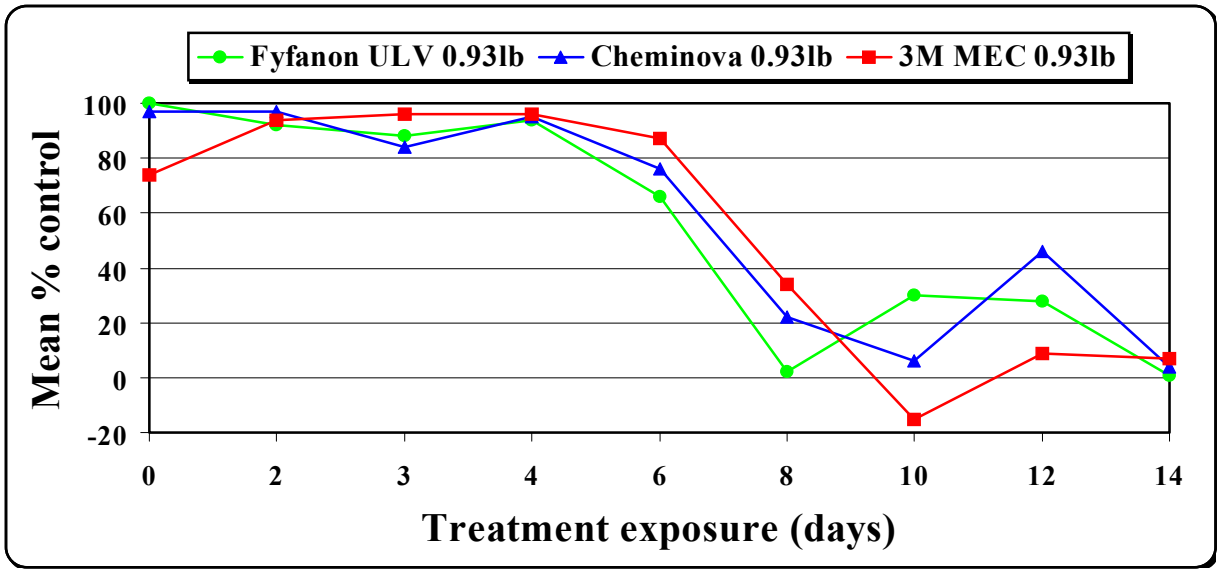

Figure 4. Mortality of boll weevils exposed for 3 days to selected ages of residue from the 0.93lb AI/acre dose of 3 formulations of malathion aerially applied to cotton leaves.

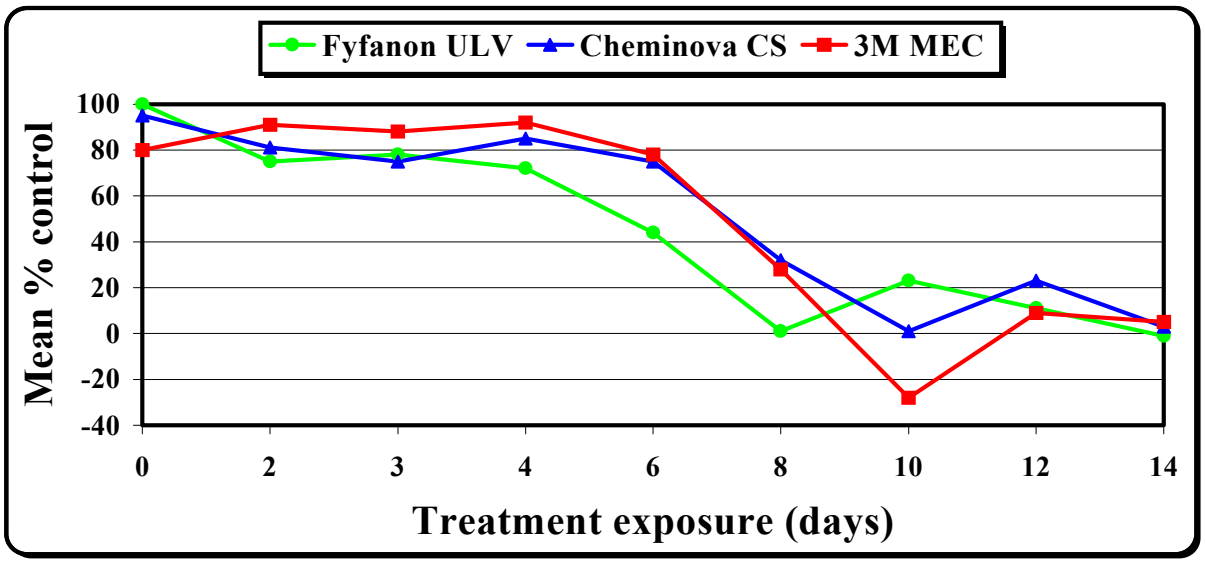

Figure 5. Average mortality of 3 combined doses (0.93, 0.77 and 0.62lb AI/acre) of 3 formulations of malathion against boll weevil in aerially applied leaf bioassay.