FIELD EVALUATION AND LEAF BIOASSAY OF SELECTED FORMULATIONS AND DOSES OF AERIALLYAPPLIED MALATHION AGAINST BOLL WEEVIL IN NEW MEXICO

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Abstract

Three formulations of malathion, each with 1 to 4 different doses, were aerially applied to cotton fields near Carlsbad, New Mexico for evaluation against boll weevil. An extensive bioassay using laboratory reared weevils and feeding and oviposition field damage estimates were used to assess the activity level of the different treatments compared to untreated weevils and plots. Mortality data resulting from all treatments for residue ages of 0, 2, 4, 6, 8, 10, and 12 days are shown. Feeding and oviposition damage data is shown for all treatments at 3, 7 and 14 days after application.

No differences in activity were demonstrated between the Cheminova and Griffin formulations at the program high dose of 0.93 lb AI/acre (12 fl oz/acre). Standard doses of both formulations lost activity between 4 and 6 days after treatments. Lower than traditional doses of Fyfanon ULV showed excellent activity equal to the high dose for at least 2 days after treatment.

All 3 doses of encapsulated malathion demonstrated activity equal to the standard dose for 2 days. Four day old residues of the high dose of encapsulated malathion, 0.77 lb AI/acre, showed a significant increase in performance over the equivalent standard dose, 80% vs. 47% respectively. Six through 12 days old residues of the high dose of encapsulated malathion continued to perform statistically better than the equivalent Fyfanon ULV dose. Numerically, 12 day old residues of encapsulated malathion in increasing dose rank order, produced mortalities, 1.5, 4.5 and 10 times greater than the 0.77 lb AI/acre Fyfanon standard dose. The increase in mortality among the 3 doses of encapsulated malathion suggests a 12 fl oz equivalent dose may produce 75% to 80% mortality. This level would be very similar to what the traditional dose showed after 4 days in this study. This possibility is extremely exciting because if such a level of activity is confirmed for that period of time, a doubling of the current interval between applications of malathion may be possible in the future. The data strongly suggests that an encapsulated dose equivalent to the current 12 fl oz Fyfanon treatment may demonstrate acceptable activity for ca. 2 weeks. Such improvement in treatment effectiveness could reduce overall pesticide load and application costs for boll weevil.

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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 impacted 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, with active acreage predicted to increase by another 800,000 acres in year 2000 (personal communication, William Grefenstette, 1999). This increasing need of pesticide for boll weevil eradication efforts, althoughrelatively short-term, makes the development of less expensive or longer lasting treatments extremely beneficial.

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 AI/acre for acceptable results, their development is highly desirable.

In an initial bioassay 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 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 hand applied small field plot studies, conducted in New Mexico, showed a trend of longer residual activity for the encapsulated formulation compared to the standard malathion (Reuter et al, 1999 - Report) (Reuter et al, 1998b – Report).

As an alternative or in addition to longer lasting treatments, new strategies may substantially reduce the amount of pesticide used. One method may be to use less than the traditional dose and accept less than maximum mortality. In situations where many repeated treatments are anticipated, the goal of maximum mortality with each treatment may not be the most economical. By reducing the pest mortality goal for each treatment by a few percentage points, while maintaining a cumulative efficacy, highly significant savings in overall pesticide use and program cost may be achieved. This strategy (Larsen and Foster, 1996) has been demonstrated with success against grasshoppers. On rangeland where malathion is used to control large outbreaks of grasshoppers a 10% to 15% decrease in mortality translates into a 60-63% savings over traditional pesticide costs, while producing better economic returns (Foster et al, 1998).

In order to assess the potential for encapsulated malathion in a traditional role against boll weevil and to begin to explore the possibilities of new strategies which rely on less aggressive short term mortality goals, the following field study was conducted.

General Objectives

1. Compare boll weevil mortalities resulting from 3 doses of encapsulated malathion and 2 Fyfanon ULV eradication dose standards.
2. Compare boll weevil mortalities resulting from similar doses of Atrapa ULV and Fyfanon ULV formulations of malathion.
3. Develop boll weevil mortality levels which result from several doses of malathion that are lower than currently used standards.

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 the same grower. 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.

Nine 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 full aerially applied swaths. Plots were of sufficient separation to ensure no contamination from test treatments or from any crop treatments to nearby fields. All fields containing plots were under the general management of the same grower. All test 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 the plots was sprayed with 1 of 8 treatments. One plot was left untreated as a control. Assignment of treatments was random. The Cheminova encapsulated "A" formulation was aerially applied at 0.77 lbs AI/acre, 0.62 lbs AI/acre and 0.46 lbs AI/acre on July 29th, 1999 in total volumes of 22 fl oz/acre, 18 fl oz/acre, and 14 fl oz/acre respectively. These rates are equivalent to 10 fl oz/acre, 8 fl oz/acre, and 6 fl oz/acre respectively of the currently used malathion standard, Fyfanon ULV. Depending on the individual eradication effort, the traditional program standards are 12 fl oz/acre and 10 fl oz/acre of Fyfanon ULV. While the encapsulated formulation may be mixed with water, all treatments in this study were applied undiluted. These treatments were compared to aerial treatments of Fyfanon ULV applied at 12 fl oz/acre (0.93 lb AI/acre), 10 fl oz/acre (0.77 lb AI/acre), 8 fl oz/acre (0.62 lb AI/acre), and, 6 fl oz/acre (0.46 lb AI/acre). Also included for comparison was the Griffin formulation of malathion, Atrapa ULV, applied at 12 fl oz/acre (0.93 lb AI/acre). All non-encapsulated treatments were applied on July 30, 1999.

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 application. Ground personnel also provided guidance and ensured acceptable operating parameters during treatments. 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 which resulted in delivery of spray within 1 percent of the desired rate per acre, for each of the 8 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. Encapsulated treatments, 0.77 lb AI/acre, 0.62 lb AI/acre and 0.46 lb AI/acre, were applied at 120 mph and 42 psi through 11, 9, and 7 (8003 size) tips respectively. The Fyfanon ULV treatments, 0.93 lb AI/acre, 0.77 lb AI/acre, 0.62 lb AI/acre and 0.46 lb AI/acre were applied at 125 mph and 39 psi, 41 psi, 45 psi and 39 psi respectively through 10, 8, 6, and 5 (8002 size) tips respectively. The single Atrapa ULV treatment, 0.93 lb AI/acre, was applied at 125 mph and 39 psi through 10 (8002 size) tips.

Winds during application were less than 2 mph for all plots except for one plot where winds ranged from 2-3 mph. Other conditions recorded during application are summarized in Table 1.

Field Damage

Field damage was evaluated by collecting 1/3 grown squares and examining for feeding or oviposition damage. 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 plots. Fifty squares were also collected from each of 20 control plots which were interspersed between treated plots, but at least 400 feet from treated areas. Collected squares were evaluated in the lab for boll weevil feeding or oviposition damage. Squares were dissected when there was any doubt about the nature of the damage.

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 9 treatments, including the untreated check, consisted of 10 replicates each containing 10 test insects for each selected day of evaluation. Therefore 700 weevils were used for each treatment. Cotton leaves from 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, and 12 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 (100mm x 15mm plastic petri dishes modified with a screen-covered 45mm 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, ARS Gast Boll Weevil Rearing Facility at Mississippi State University. 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 considered dead only when no movement of any kind was detected.

Droplet Deposition

Oil sensitive spray cards (Ciba-Geigy 52x72mm) were stapled to leaves in the cotton canopy to obtain a general estimate of the density of spray droplets deposited for each non-encapsulated treatment. 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 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, 2, 1 cm^2 areas on each card were counted 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 using the Tukey multiple comparison test (Systat® 6.0) was used to separate means. Results from the analysis with the observed data are presented. Differences in treatment means for percent feeding or oviposition damaged squares were compared with Tukey-Kramer's test (SAS-JMP 1998) with data transformed with a square root arcsin.

Results and Discussion

The mean percentage mortality of boll weevils exposed to residual treatments of 0-12 days for each of 8 treatments and the untreated control population is shown in Table 2. Mortality is shown for the progressive exposure of weevils for 1 through 5 days. Generally, results and discussion will focus on mortality recorded on the fifth day of exposure.

At 5 days after weevils were exposed to treatments of 4 day old residuals, all treatments produced mortality significantly greater than what occurred in the untreated population, except the two lower doses of Fyfanon ULV (0.62 lb AI/acre and 0.46 lb AI/acre) and the lowest dose of encapsulated malathion (0.46 lb AI/acre). Six day old residual treatments resulted in only the 2 highest doses of encapsulated malathion producing mortalities significantly greater than what occurred in the untreated population (73% and 47% vs. 7% respectively).

Unexplained high mortality occurred in the untreated check population when 8 day old residuals were tested, thus precluding any treatments from performing significantly at this residual age. However, 10 day old residual treatments of 0.77 lb AI/acre encapsulated malathion resulted in numerically higher mortality than the untreated population, and 12 day old residual treatments of the same dose material produced significantly higher mortality than the untreated population.

At 3 days after treatment no significant differences in infested squares or feeding damage was detected between any of the plots including the untreated control. All plots showed some damage and were indicative of the infestation of the area (Table 3-4).

At 7 days after treatment only plots treated with standard program doses of 0.93 lb AI/acre of Fyfanon ULV and Atrapa ULV and the 0.77 lb AI/acre dose of Fyfanon ULV resulted in significant reduction in infested squares compared to the untreated plots. However, there was no significant difference in feeding damage between any of the treated plots and the untreated plots.

At 14 days after treatment the standard 0.93 lb AI/acre doses of Fyfanon ULV and Atrapa ULV resulted in the lowest numerical levels of infested squares, 4% and 9% respectively. This compared to 18% infested squares in the untreated areas.

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.

Atrapa ULV and Fyfanon ULV

As expected, no significant difference in mortalities resulted from the 2 formulations at the standard dose of 0.93 lb AI/acre for any ages of residual and intervals of exposures examined in this study (Table 2). In terms of mortality, no advantages were demonstrated for either formulation. However, both formulations at the traditional dose lost significant activity between 4 and 6 days after application. At 6 days after treatment, residuals of both formulations failed to produce significant mortality.

No differences in feeding or infested square damage were detected between the 2 formulations at an equivalent dose at any of the post treatment intervals examined except after 14 days (Table 3-4). The Atrapa ULV plot resulted in a significantly lower level of infested squares compared to the Fyfanon ULV plot. Feeding damage was also lower in the Atrapa ULV plot on day 14 with 17% feeding damage but not significantly lower than the 43% feeding damage in the equivalent Fyfanon ULV plot. This lower rate of damage in the Atrapa ULV plot suggests that it might have longer residual activity but this result was not consistent with the bioassay results which indicated both formulation were similar in residual activity. Again, damage data in this study should be viewed with caution for reasons earlier mentioned.

Encapsulated Malathion

The data recorded at 1 and 2 days of exposure appear to indicate that treatments of encapsulated malathion are slow to produce high levels of mortality (Table 2). However, in this study no distinction was made between sick or functionally dead weevils and physically dead weevils where no movement at all was detectable. The majority if not all of the weevils which were survivors on day 1 and day 2, but were recorded as mortality on day 3 were functionally dead. They could still demonstrate some movement but were incapacitated to the point of not being capable of causing damage or producing offspring to add to the population. Future studies of this nature should differentiate between functional mortality and physical mortality.

Compared to the standard 0.77 lb AI dose of Fyfanon, all doses of encapsulated malathion performed statistically equal through 2 days of residual. Four day old residuals of the high dose of encapsulated malathion showed a significant increase in performance over the equivalent standard dose, 80% vs. 47% respectively (Fig. 2). Six days through 12 day old residuals of the high dose of encapsulated malathion continued to perform statistically better than the equivalent Fyfanon ULV (Fig. 2) . Numerically, 12 day old residuals of encapsulated malathion in increasing dose rank order produced mortalities 1.5, 4.5 and 10 times greater than the 0.77 lb AI/acre Fyfanon standard dose (Fig. 2).

The increase in mortality between the 3 doses of encapsulated malathion is extremely important to future work. Each 2 fl oz standard Fyfanon equivalent of encapsulated malathion resulted in an ca. doubling of the mortality (Fig. 3). Such increases suggest a 12 oz equivalent dose may produce 75-80% mortality. This level would be very similar to what the traditional dose showed after 4 days in this study. This possibility is extremely exciting because if such a level of activity is confirmed for that period of time, a doubling of the current interval between applications of malathion may be possible in the future. Additional studies are planned to further explore residual activity levels of other doses of this and other encapsulated formulations of malathion.

When feeding and oviposition (infested squares) damage was examined, there was no significant difference between plots treated with equivalent doses of Fyfanon ULV and encapsulated malathion with 1 exception (Table 3-4). At 7 days after treatment significantly more feeding damage resulted from the 0.62 lb AI/acre Fyfanon ULV treatment compared to the equivalent encapsulated malathion treatment, 27% vs 6% respectively.

At doses of 0.46 lb AI/acre through 0.77 lb AI/acre, both Fyfanon ULV and encapsulated malathion treatments performed in dose rank order relative to feeding damage at all intervals examined. However, no trend could be seen for infested squares.

It is important to note that when combined feeding damage for the 3 doses is compared between the Fyfanon and encapsulated formulations, the plots treated with encapsulated malathion resulted in less feedings damage at 2 of the 3 intervals (Table 5). Also when combined oviposition damage for the 3 doses in common are compared, plots treated with encapsulated malathion resulted in less oviposition damage at 2 of the 3 intervals. All of these feeding and oviposition trends are consistent with the bioassay results.

Fyfanon ULV Doses

There was no significant difference between mortalities resulting from treatments of 0.93 lb AI/acre or 0.77 lb AI/acre of Fyfanon ULV at any residual age (Table 2) (Fig. 4). The only suggestion of any advantage in terms of increased mortality occurred with residuals 4 days old. At this age the 12 oz treatment was numerically, but not significantly, superior to the 10 oz treatment, 73% vs. 47% respectively. All of the lower doses of Fyfanon only produced mortalities significantly greater than what occurred in the untreated population through residuals 2 days old. However, only the 0.77 lb AI/acre dose of the 3 lower doses produced significant mortality with 4 day old residuals.

At 3 days after treatment there was no significant difference in infested squares resulting from any of the 4 doses of Fyfanon ULV (Table 4). However by day 7 only the 0.93 lb AI/acre dose resulted in significantly lower damage than the 0.46 lb AI/acre dose and the untreated plots. There was no significant difference between the 0.62 and the 0.93 doses at this interval. At 14 days no significant differences were seen between any of the 4 doses and the untreated population.

The lower dose data is very valuable. It provides an indication of what can be expected if misapplication results in such levels of exposure for boll weevil. Additionally, data from the two lowest doses of Fyfanon may be used in future modeling efforts to determine if more economic use of insecticide can occur when numerous repeated treatments of the same field are expected. For this to occur, less aggressive mortality goals must be proven acceptable.

Droplet Deposition

The number of spray droplets deposited per cm² for all non-encapsulated treatments are shown in Table 6. For some unexplained reason the Atrapa ULV formulation produced 25% more droplets/cm² than the Fyfanon ULV formulation. Additionally it was noted that finer droplets were easier to detect on cards sprayed with Atrapa ULV compared to Fyfanon ULV at the same dose, total volume/acre and aircraft spray system arrangement. Earlier studies by K.C. Reuter et al. (Report) 1999 of the USDA, APHIS revealed that when both materials were evaluated with static tests on laboratory bench mounted spray system for flow rates, Atrapa flowed slightly faster (0.5% to 0.72%) than Fyfanon ULV. However, this very minor increase in flow rate would probably not account for the disparity between formulations recorded in this study.

Droplet data for all low doses tested are shown in Table 6. The different doses produced mean droplet/cm² values in dose rank order. The values ranged from 13.5 droplets/cm² for the 6 fl oz/acre dose to 27.6 droplets/cm² for the 12 fl oz/acre dose. Based on 12 fl oz/acre, the droplets/cm² for the 8 fl oz/acre and 10 fl oz/acre treatments were 33% and 32% less then expected. The 6 fl oz/acre dose produced an expected density of droplet.

Droplets of encapsulated material were difficult to analyze on either oil or water sensitive spray cards. However, many larger droplets were easily visible with the unaided eye on target cotton leaves (Fig. 5).

Conclusion

The results of this study indicate no substantial differences between the Cheminova and Griffin formulations of malathion in terms of bioassay mortality, and field damage at the standard program dose of 0.93 lb AI/acre. However, more droplets were produced with the Griffin formulation compared to the Cheminova formulation. The 0.77 lb AI/acre dose of encapsulated malathion demonstrated significant activity for 8 days longer than the equivalent Fyfanon ULV dose. This total activity period was 3 times longer than the period of activity shown by the current standard. Our data strongly suggest that an encapsulated dose equivalent to the current 12 fl oz Fyfanon treatment may demonstrate acceptable activity for ca. 2 weeks. Such improvement in treatment effectiveness could reduce overall pesticide load and application cost for boll weevil.

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Table 1. Meteorological conditions recorded during the aerial application of selected treatments of malathion near Carlsbad, New Mexico, 1999.

Trt *		Time	Wind(mph)/dir.	Air °F	Soil°F
Ec - 0.77	Start	6:15am	2-3 / E	68.5	69.0
	End	6:17am			
Ec - 0.62	Start	6:30am	1-2 / NE	72.0	71.5
	End	6:32am			
Ec - 0.46	Start	6:50am	0-1 / E	75.0	
	End	6:52am	0-1 / E	73.0	73.0
Fy - 0.93	Start	6:06am	0-1 / NE	69.0	68.0
	End	6:08am	0-1 / NE		
Fy - 0.77	Start	6:45am	1.5 / E	73.3	73.6
	End	6:47am	1.5-2 / E		
Fy - 0.62	Start	7:02am	1-1.5 / NE	76.2	76.0
	End	7:06am	0-1 / E		
Fy - 0.46	Start	6:23am	1.5 / NE	70.9	70.4
	End	6:26am	1.5 / NE		
At - 0.93	Start	7:37am	0-1 / E	79.0	76.0
	End	7:40am	0-1 / E		

* Ec = encapsulated malathion, Fy = Fyfanon ULV, At = Atrapa ULV and following numbers indicate pounds of active ingredient applied per acre.

Table 2. Mean percentage mortality of boll weevils after 1 to 5 days of exposure to 0 to 12 day old malathion treated cotton leaves.

	Days After Exposure				
Trt *	**1**	**2**	**3**	**4**	**5**
0 day					
Fy0.93	99a	99a	100a	100a	100a
Fy0.77	98a	100a	100a	100a	100a
Fy0.62	95a	99a	100a	100a	100a
Fy0.46	91a	96a	100a	100a	100a
At0.93	99a	100a	100a	100a	100a
Ec0.77	53b	87a	92a	97a	99a
Ec0.62	52b	87a	97a	99a	100a
Ec0.46	52b	86a	92a	98a	99a
Ut	2c	2b	3b	5b	9b
2 day					
Fy0.93	99a	100a	100a	100a	100a
Fy0.77	97a	99a	100a	100a	100a
Fy0.62	94a	97a	98a	98a	98a
Fy0.46	85a	91ab	95a	97a	97a
At0.93	100a	100a	100a	100a	100a
Ec0.77	58b	86abc	93a	97a	98a
Ec0.62	56b	80bc	91a	93ab	97a
Ec0.46	44b	71c	77b	81b	89a
Ut	1c	2d	2c	5c	13b
4 day					
Fy0.93	27a	46a	57a	61a	73ab
Fy0.77	10b	24abcd	30abc	39ab	47bc
Fy0.62	4b	14bcd	19bc	21bc	30cd
Fy0.46	9b	11cd	18bc	21bc	30cd
At0.93	13ab	43a	47ab	52ab	68ab
Ec0.77	14ab	37abc	61a	72a	80a
Ec0.62	14ab	41ab	60a	70a	80a
Ec0.46	5b	13bcd	21bc	23bc	33cd
Ut	2b	2d	2c	3c	9d
6 day					
Fy0.93	5b	8b	16bc	18bc	24bc
Fy0.77	1b	8b	12bc	15c	21c
Fy0.62	2b	13b	20bc	21bc	29bc
Fy0.46	2b	6b	10bc	15c	16c
At0.93	7ab	16b	25b	27bc	32bc
Ec0.77	18a	46a	55a	66a	73a
Ec0.62	9ab	17b	29b	40b	47b
Ec0.46	4b	10b	12bc	12c	15c
Ut	0b	0b	0c	4c	7c
8 day					
Fy0.93	2b	2c	3c	9c	15b
Fy0.77	1b	2c	3c	10c	18b
Fy0.62	2b	3c	4c	9c	14b
Fy0.46	0b	1c	1c	6c	12b
At0.93	1b	1c	1c	5c	8b
Ec0.77	17a	28ab	32ab	37ab	53a
Ec0.62	26a	41a	42a	48a	52a
Ec0.46	4b	11bc	14c	17bc	21b
Ut	2b	9c	16bc	28abc	52a
10 day					
Fy0.93	3a	3a	4bc	8ab	10b
Fy0.77	1a	2a	2c	5b	9b
Fy0.62	1a	3a	3bc	9ab	11b
Fy0.46	1a	2a	3bc	5b	9b
At0.93	1a	2a	2c	5b	8b
Ec0.77	6a	11a	18a	20a	30a
Ec0.62	4a	9a	14ab	15ab	19ab
Ec0.46	0a	2a	3bc	5b	9b
Ut	0a	1a	6bc	11ab	16ab
12 day					
Fy0.93	0a	2a	3a	5b	6b
Fy0.77	0a	0a	1a	4b	4b
Fy0.62	0a	0a	1a	2b	5b
Fy0.46	0a	0a	0a	3b	7b
At0.93	0a	1a	3a	6b	11b
Ec0.77	2a	4a	9a	21a	40a
Ec0.62	6a	7a	7a	9ab	18b
Ec0.46	0a	0a	1a	2b	6b
Ut	0a	0a	2a	5b	16b

* Fy = Fyfanon ULV, At = Atrapa ULV, Ec = Encapsulated malathion, Ut = untreated control and following numbers indicate pounds of active ingredient applied per acre. Values within each residual age in the same column followed by the same letter are not significantly different (ANOVA, $P \leq 0.05$).

Table 3. Boll weevil feeding damage to squares collected 3-14 days after treatment with selected formulations and doses of malathion.

	Rate		% feeding damaged squares *		
Treatment	**Fl oz**	**Lb AI/ac**	**Day 3**	**Day 7**	**Day 14**
Fyfanon ULV	6	0.46	12a	36a	50a
	8	0.62	8a	27a	50a
	10	0.77	6a	14bc	22bc
	12	0.93	16a	17abc	43abc
Encapsulated	14	0.46	23a	23ab	44ab
	18	0.62	10a	6c	33abc
	22	0.77	8a	7c	30abc
Atrapa ULV	12	0.93	7a	13bc	17c
Check	---		14abc	19abc	23bc

* Means within a column followed by similar letters are not significantly different Tukey-Kramer ($P<0.05$).

Table 4. Boll weevil egg and larvae infested squares at selected days after treatment with selected formulations and doses of malathion.

	Rate		% oviposition *		
Treatment	**Fl oz**	**Lb AI/ac**	**Day 3**	**Day 7**	**Day 14**
Fyfanon ULV	6	0.46	9a	7ab	21a
	8	0.62	18a	5abc	19a
	10	0.77	21a	2bc	25a
	12	0.93	6a	0c	9a
Encapsulated	14	0.46	18a	12ab	21a
	18	0.62	7a	3abc	11a
	22	0.77	15a	10ab	19a
Atrapa ULV	12	0.93	7a	0c	4b
Check	---		16a	10a	18a

* Means within a column followed by similar letters are not significantly different Tukey-Kramer ($P<0.05$).

Table 5. Boll weevil feeding and oviposition damage to squares collected 3-14 days after treatment with 3 combined doses of Fyfanon ULV and encapsulated malathion.

Treatment Lb AI/acre	Percentage damage on indicated days		
	3	7	14
	Feeding Damage		
Fyfanon ULV 0.46+0.62+0.77	26	77	122
Encapsulated 0.46+0.62+0.77	41	36	107
	Oviposition Damage		
Fyfanon ULV 0.46+0.62+0.77	48	14	65
Encapsulated 0.46+0.62+0.77	40	25	51

Table 6. Mean number of spray droplets per cm^2 on oil sensitive spray cards from 5 aerially applied malathion boll weevil treatments - Carlsbad, New Mexico, 1999.

Formulation	Rate lb. AI/acre	Tip size (no.)	Droplets	Expected Droplets *
Atrapa ULV	0.93	8002 (10)	34.6	
Fyfanon ULV	0.93	8002 (10)	27.6	
Fyfanon ULV	0.77	8002 (8)	17.3	22.9
Fyfanon ULV	0.62	8002 (6)	13.8	18.4
Fyfanon ULV	0.46	8002 (5)	13.5	13.8

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

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

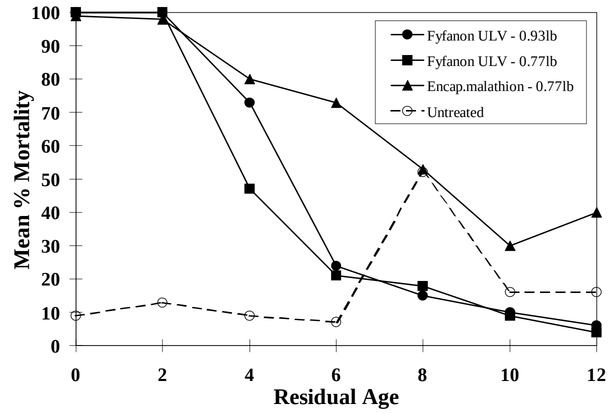

Figure 2. Comparison of boll weevil mortalities resulting from treatments of encapsulated malathion and 2 program standard doses of currently used malathion.

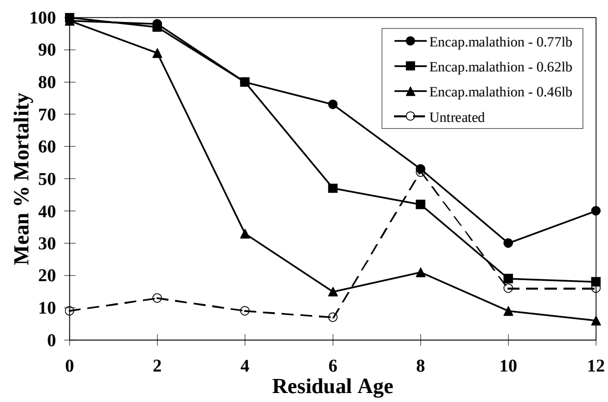

Figure 3. Mortality of boll weevils exposed for 5 days to selected ages of residue from 3 doses of encapsulated malathion aerially applied to cotton leaves.

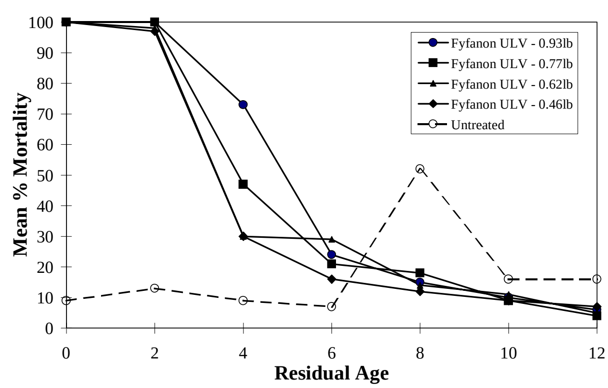

Figure 4. Mortality of boll weevils exposed for 5 days to selected ages of residue from 4 doses of malathion aerially applied to cotton leaves.

Figure 5. Aerially applied encapsulated malathion droplets on cotton leaf.