APPLICATION OF REDUCED RATES OF TECHNICAL MALATHION APPLIED AS ULTRA LOW VOLUME IN OILS

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ABSTRACT

Aerial application tests of malathion ultra low volume (ULV) mixed in once-refined cottonseed (CSO) and horticultural mineral oils (HMO) were conducted in 1998 and 1999 to determine toxicity to boll weevils with leaf bioassays. The HMO's used in these tests were: Orchex® 796, and WS2908, an Orchex® 796 formulation with drift retardant. Mortalities showed that a 6 oz/A (208 g [AI]/ha) rate of malathion ULV mixed with 26 oz/A (1.9 L/ha) of CSO was as effective against boll weevils as a 12 oz/A (415 g [AI]/ha) rate of undiluted malathion ULV. Efficacy of 6:26 (0.44:1.9 L/ha), 6:10 (0.44:0.73 L/ha), 7:18 (0.51:1.3 L/ha), 8:8 (0.58:0.58 L/ha), and 10:0 oz/A (0.73:0 L/ha) ratios of malathion ULV:CSO against boll weevils was determined. Results showed that 6 (208 g [AI]/ha) and 8 oz/A (277 g [AI]/ha) rates of malathion ULV mixed with 10 (0.73 L) and 8 (0.58 L) oz/A of cottonseed oil, respectively, can be as effective as an undiluted 10 oz/A (346 g [AI]/ha) rate for the first 2 - 3 days after treatment. Application of the 7:18 ratio deposited greater amounts of malathion on main stem sections 9 - 12" below the terminal than the 8:8 ratio. Malathion residues accumulated on leaf surfaces during rain free periods in August after repeated applications of technical malathion alone and when diluted with CSO.

INTRODUCTION

Technical malathion is being used as an ultra-low-volume (ULV) spray in the Boll Weevil Eradication Program. Increases in the cost of malathion ULV and it's application have encouraged research on reduced rates of malathion ULV for boll weevil control. As a result, the rate of malathion ULV has been reduced from 16 oz to 10 - 12 oz/A.

The use of oils may be a means to further reduce costs of malathion ULV application because they are less expensive than malathion. Cottonseed oil (CSO) is a vegetable oil which has been shown to enhance the application of some insecticides against pests of cotton. In a study conducted by Ochou et al. (1986), both vegetable (soybean and cottonseed) and petroleum oils synergized various pyrethroids against larvae of tobacco budworm, *Heliothis virescens* (Fab.), and adult house flies, *Musca domestica* L. Conversely, they found that the same oils were less synergistic or even antagonistic with more water-soluble organophosphorus and carbamate insecticides. Similarly, Treacy et al. (1986) demonstrated that soybean oil enhanced toxicity of the pyrethroid, cyfluthrin, against the boll weevil, *Anthonomus grandis grandis* Boheman, more that it did for selected carbamate and organophosphorus insecticides.

While cottonseed oil has been used as an adjuvant of malathion ULV, little research has been done on the application of reduced rates of malathion ULV in CSO for boll weevil control. Neither has research been conducted on the application of malathion ULV in horticultural mineral oils (HMO) which have been shown to enhance insecticide and herbicide toxicity. Wolfenbarger and Guerra (1986) found permethrin/HMO mixtures to be more toxic to boll weevils than a permethrin/cottonseed oil mixture.

HMO's have some advantages over vegetable oils. HMO's have greater ability to penetrate insect cuticles than vegetable oils. For example, de Licastro et al. (1983) found that HMO's increased the rate of cuticular penetration by parathion formulations in the conenose bug, *Triatoma infestans* (Klug). HMO was also found to increase cuticular penetration of avermectin B1 in southern armyworm, *Spodoptera eridania* Cramer (Anderson et al. 1986). Jones et al. 1998 showed that topical applications of malathion mixed with HMO was more toxic to boll weevils than malathion mixed with CSO.

HMO's are straight chain hydrocarbons that are consistent in their properties in comparison to vegetable oils which vary widely in composition. Because of their synthetic composition, HMO's can be modified for specialized applications. Exxon Chemical Co. recently developed a particle-size modifier that increases the droplet size of HMO's and should be useful for drift reduction. One disadvantage of HMO's is that they are not miscible with malathion. Therefore, a compatibility additive must be used to mix technical malathion with HMO which will increase the cost of application.

The objectives of this research were to compare the performance of CSO with that of HMO's as adjuvants for malathion ULV aerial application. Efficacy and longevity of different ratios of technical malathion:adjuvant applied ULV were also determined. We also determined the amount of malathion residue in different canopy levels following applications and malathion residues following rainfall were also made.

MATERIALS AND METHODS

Evaluation of oil adjuvants for technical malathion were conducted in field experiments during 1998 and 1999. All treatments were applied at ULV using an Air Tractor 402 aircraft. The aerial application parameters are given in Table 1. Boll weevils used in these tests were obtained from the USDA-ARS Gast Rearing Laboratory at Mississippi State, MS.

TABLE 1 . Aerial Application Parameters for Malathion/Cottonseed Oil Mixtures.

				Nozzles	
Rate (oz/A)	Volume (oz/A)	Speed	Pressure	Number	Size
6	32	135	30	18	8004
6	16	135	30	18	8002
7	25	135	32	18	8003
8	16	135	30	18	8002
10	10	135	30	11	8002

Oil Adjuvant Test - 1998. The effects of three oil adjuvants on the efficacy of technical malathion were determined. Once-refined cottonseed oil was obtained from Yazoo Valley Oil Mill, Greenwood, MS. Orchex® 796, an EPA registered horticultural mineral oil, and

WS2908A, an experimental Orchex® 796 formulation were provided by Exxon Chem. Co., Baytown, TX. WS2908A is a blend of Orchex® 796 and a droplet size modifier. Mixing malathion ULV with both Orchex® 796 and WS2908A required a compatibility agent, HM9737, developed by Helena Chemical Co. Technical malathion (Fyfanon ULV 96.8%, Cheminova Agro, Lemvig, DK) was used in all tests. The three oil adjuvants were mixed with technical malathion at 6 oz/A (208 g [AI]/ha) and applied in a total volume of 32 oz/A (2.34 L/ha). A 12 oz/A (415 g [AI]/ha) application of technical malathion was used as a standard. The treatments were applied by aircraft to 1.34 A (0.54 ha) plots on 8 and 21 September. Two swaths of the aircraft were made in each plot and six measurements were taken within each plot. Bioassays of treated leaves using boll weevils (3-5 d old) were conducted at 0, 1, 2, and 3 days after treatment. The data were analyzed as a randomized complete block with 5 treatments replicated in time. Measurements within each plot were subsamples.

Cottonseed Oil: Malathion Ratio Test - 1999. Technical malathion was mixed with once refined cottonseed oil at the following ratios of ounces of technical malathion to ounces of CSO: 6:10 (0.44:0.73 L/ha), 6:32 (0.44:2.34 l/ha), 7:18 (0.51:1.32 L/ha), and 8:8 (0.58:0.58 L/ha). An application of undiluted malathion ULV at 10 oz/A (0.73 L/ha) was used as a standard. Treatments were applied with an Air Tractor 402 aircraft to 1.34 A (0.54 ha) plots on 12, 21, and 27 July. Each plot consisted of two swaths of the aircraft and six measurements were made within each plot. The data were analyzed as a randomized complete block with 6 treatments replicated in time. Measurements within each plot were subsamples.

7:18 and 8:8 ratios were applied to 10 A (4.05 ha) plots on 11, 16, 23, and 29 August as part of the diapause control program in the North Delta of Mississippi. Applications by the eradication program on 4, 10, 13, 18, and 26 August to a 10 A (4.05 ha) field were monitored for efficacy and longevity by leaf bioassays and residue analyses. Data from applications made during August were not statistically analyzed.

Bioassay. Bioassays were conducted on leaves at 0 - 3 d after application during July and 0 - 6 d after application in August. Five leaves per subsample (30 per treatment) collected each day from the 4th node down from the terminal were individually placed in plastic petri dishes (100 mm dia.) containing five boll weevils. Petri dishes containing leaves and boll weevils were held at 26.7E C and in a 12:12 photoperiod. Boll weevil mortality was determined by pinching the rostrum of the weevil at 48 h after exposure to treated leaves. Those that did not move were recorded as dead.

Residue Analysis - 1999. Malathion residues were obtained from leaves collected at the same times and manner as leaves for bioassay. Leaf disks (2.54 cm diam.) cut from leaves were rinsed in iso-octane. In addition, leaves from the top and mid-canopies and mainstem sections 9 - 12" (22.9 - 30.5 cm) down from the terminal were collected to determine canopy penetration of malathion. Residue analyses were run on a Hewlett Packard 5890 gas chromatograph equipped with a flame photometric detector and auto-sampler. The gas chromatograph was operated with Chemstation (Hewlett Packard) software. The parameters of the residue analysis method were as follows: injector temperature, 200°C; detector temperature, 200°C; oven program, 120°C initial temperature with a 25°C/min increase to 250°C for 1 min, then a 25°C/min increase to 280°C for 4 min. A Hewlett Packard Ultra-1 cross-linked methyl silicone gum phase column (25 m by 0.32 mm by 0.52 µm) with a 2.65 ml/min flow of helium was used. Retention time of malathion was 5.597 min.

Data Analysis. All data were subjected to an ANOVA using SAS's PROC MIXED (Littell et al. 1996). Least square means were separated using the PDIFF option.

RESULTS AND DISCUSSION

In 1998, comparison of oil adjuvants showed that CSO was a more effective adjuvant than Orchex® 796 or WS2980 (Table 2). Mortality of boll weevils placed on leaves treated with malathion mixed in Orchex® 796 and in WS2908 was not as high as those on leaves treated with malathion mixed in cottonseed oil. At 3 days after application, mortality of boll weevils on leaves treated with the reduced rate of malathion in CSO (92%) was not different from those on leaves treated with an application of 12 oz/A of technical malathion (92%).

TABLE 2. Average Percent Mortality (48 h) of Boll Weevils in Leaf Bioassays of Cotton Treated with Malathion Mixed in Different Oils on 8 and 21 September 1998.

Adjuvant[a]	Rate (oz/A)	Days after application 0[b]	1	2	3
Cottonseed oil	6	100±0[c] a	100±0 a	92±2 b	92±2 a
Orchex® 796	6	95±2 b	82±3 b	72±3 c	54±3 b
WS2908	6		64±1 c	51±2 d	37±3 c
Undiluted	12	100±0 a	100±0 a	100±0 a	92±3 a

[a]Adjuvant treatments were applied in a 32 oz/A volume.
[b]Day 0 mortalities are from the first application only. WS2908 was not included in the first application.
[c]Least square means in a column not followed by the same letter are significantly ($P<0.05$) different as determined by PDIFF (Littell et al. 1996).

In 1999, all tests with technical malathion were conducted with CSO because it was the most effective adjuvant. Boll weevil mortality on leaves treated with the 6:26 and 7:18 ratios of malathion to CSO was equivalent to the 8:8 ratio, while the low-rate/low-volume (6:10) ratio produced the lowest mortality (Tables 3 and 4). Mortality was highest on leaves treated with the 10 oz/A application. Malathion residues on cotton leaves were indicative of the concentration of the mixture applied and diminished over time (Table 3). These results suggest that 6 and 8 oz/A rates of malathion applied with 8 - 10 oz/A of CSO can be as effective as an undiluted 10 oz/A rate for the first 2 - 3 days after treatment.

Increasing the volume of application increases plant coverage. When malathion was applied in a higher volume of CSO, as in the test comparing 8:8 and 7:18 ratios of malathion:CSO, greater deposition occurred on the main stem at 9 - 12" down from the terminal (Table 4). However, differences in residues on leaves from the top and mid-canopy were not significantly different when the volume of application ranged from 10 to 32 oz/A (Table 5).

The longevity of malathion on the plant surface during the diapause application program in the North Delta of Mississippi in August 1999 was unexpected (Table 6) and was quite different from that seen in July (Table 3). Malathion residues accumulated during the program until a light rain washed malathion off the leaf surface on 21 August (Fig. 1). This same trend can be seen in residues from the 7:18 and 8:8 ratio applications (Fig. 1) with rain occurring on 23 August. The level of malathion on the leaf surface accumulated well beyond that deposited by the initial application of 10 oz/A applied by the program aircraft on 4 August. Accumulation of malathion on cotton leaf surfaces was also found by Wolfenbarger in tests conducted in Mexico (unpublished data). If residues accumulate on the leaf surface

TABLE 3. Average Malathion Residue (μg/cm^2) on Leaves and Percent Mortality (48 h) of Boll Weevils in Bioassays of Leaves Treated with Mixtures of Malathion and Cottonseed Oil Applied at Different Rates and Volumes by Aircraft on 12, 21, and 27 July 1999.

Malathion:CSO	Days after application							
	0		1		2		3	
	Residue	Mortality	Residue	Mortality	Residue	Mortality	Residue	Mortality
6:26	1.98[a] bc ± 0.22	99 a ± 0.4	1.04 b ± 0.14	92 a ± 2.3	0.22 c ± 0.04	64 a ± 4.0	0.10 b ± 0.03	51 b ± 5.6
6:10	1.38 c ± 0.18	98 a ± 1.8	0.61 b ± 0.09	83 b ± 3.2	0.20 c ± 0.04	38 b ± 5.0	0.11 b ± 0.04	25 c ± 4.8
8:8	2.66 ab ± 0.27	100 a ± 0.0	1.94 a ± 0.31	93 a ± 2.8	0.69 b ± 0.10	65 a ± 4.5	0.20 b ± 0.02	56 b ± 4.4
10:0	2.94 a ± 0.47	100 a ± 0.3	1.66 a ± 0.22	96 a ± 1.4	1.27 a ± 0.02	72 a ± 4.9	0.77 a ± 0.11	73 a ± 5.5

[a]Means in column not followed by the same letter are significantly ($P<0.05$) different as determined by PDIFF (Littell et al. 1996).

TABLE 4. Average Malathion Residue (μg/cm^2) Found on Leaves at the 4th Node down from the Terminal and on Main Stems 9 - 12" down from Terminal after Treatment with Malathion:Cottonseed Oil Mixtures by Aircraft on 6, 11, 16, 23, and 30 August 1999.

Malathion:CSO	Leaf	Stem
8:8	5.37[a] ± 0.57 a	0.80 ± 0.09 b
7:18	5.86 ± 0.54 a	1.07 ± 0.11 a

[a]Means in a column not followed by the same letter are significantly ($P<0.05$) different as determined by PDIFF (Littell et al. 1996).

above that needed for boll weevil control then continued application at 10 oz/A is over-treating and is not economical. These data suggest that after an adequate level of malathion has been deposited on the leaf, reduced rates of malathion can be used to maintain that level without over treating. In light of these results, reduced rates of malathion should be considered in late season diapause spray programs and in the treatment of outbreaks of weevils in late season in eradicated areas.

TABLE 5. Average Malathion Residue (μg/cm²) Found on Leaves at Top and Mid-Canopy after Treatment with Malathion:Cottonseed Oil Mixtures by Aircraft on 19 and 21 July 1999.

	Canopy Level		
Treatment	Top	Mid	% of Total @ Mid Canopy
6:26	1.54 ± 0.16[a]	0.77 ± 0.08	33
6:10	1.79 ± 0.21	1.06 ± 0.16	37
8:8	2.51 ± 0.37	0.99 ± 0.12	28
10:0	2.22 ± 0.31	0.95 ± 0.15	30

[a]Residues on leaves from the top and mid-canopies were not statistically different (PDIFF, $P<0.05$).

TABLE 6. Average Percent Mortality (48 h) of Boll Weevils in Bioassays of Leaves Treated with Malathion ULV at 10 oz/A and Mixtures of Malathion ULV and Cottonseed Oil Applied at Different Rates and Volumes by Aircraft during August 1999.

	Days after application						
Mal:CSO	0	1	2	3	4	5	6
8:8[a]	100[c] ± 0	100 ± 0	100 ± 0	95 ± 3	90 ± 4		
7:18[a]	100 ± 0	100 ± 0	99 ± 0	98 ± 1	90 ± 3		
10:0[b]	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	89 ± 4

[a]Applied by APTRU aircraft on 6, 11, and 16 August.
[b]Applied by Eradication Program on 4, 10, 13, 18, and 26 August.
[c]Means in a column not followed by the same letter are significantly ($P<0.05$) different as determined by PDIFF (Littell et al. 1996).

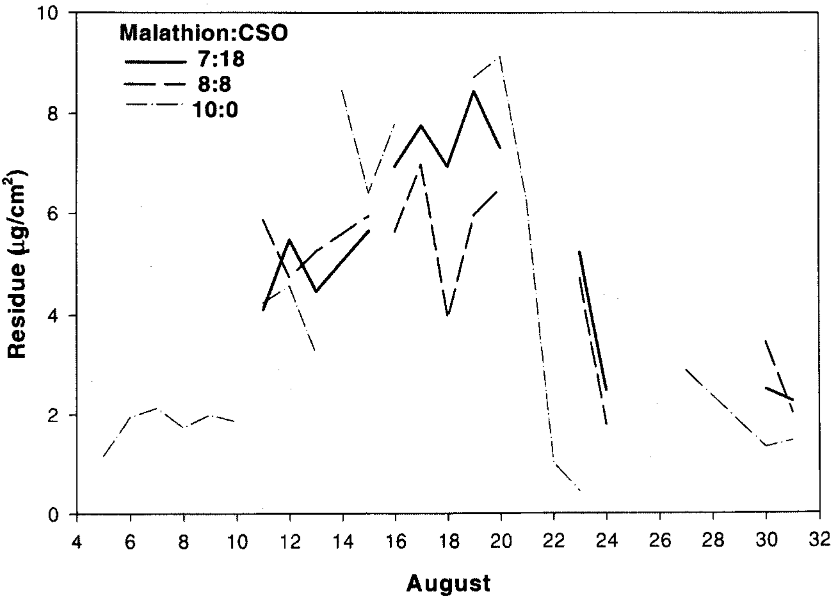

FIG 1. Malathion residues on cotton leaves during August. The 10:0 oz/A applications were made by Boll Weevil Eradication Program aircraft, while mixtures with cottonseed oil were applied by APTRU's aircraft. Rain occurred on 21 and 23 August.

A cost comparison of applications of different malathion:CSO mixtures are shown in Table 7. Application of a 8:8 or a 7:18 ratio of malathion:CSO would result in a $0.20/A savings over a 10 oz/A application of technical malathion without loss of efficacy during the first two days after application.

Table 7. Cost Savings of Reduced Rates of Malathion ($21.33/gal) in Cottonseed Oil ($2.10/gal) Compared to a 10 oz/A Application.

Malathion:CSO	Cost/A	Savings/A/Application
6:10	1.16	0.51
6:26	1.43	0.24
7:18	1.46	0.21
8:8	1.47	0.20
8:10	1.50	0.17
8:16	1.60	0.07
10:0	1.67	0

ACKNOWLEDGEMENT

Debra Gary and Ben Naron, Application and Production Technology Research Unit, assisted in this research. Debbie Boykin provided guidance for the analysis of data.

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