Effectiveness of 4,4′-Dichloro-alpha-(trichloromethyl)benzhydrol (FW-293) for Control of Citrus Mites in California

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In studies conducted in 16 southern California citrus groves, 4,4′-dichloro-α-(trichloromethyl)benzhydrol, or FW-293, was found to be effective in controlling the citrus red mite, *Metatetranychus citri* (McG.). This material also controlled the citrus flat mite, *Brevipalpus lewisi* McG., in three citrus groves but was not so effective as petroleum oil (light-medium grade) or Chlorobenzilate in controlling the citrus bud mite, *Aceria sheldoni* (Ewing). In limited field trials it caused initial reductions in populations of the six-spotted mite, *Eotetranychus sexmaculatus* (Riley), the Yuma mite, *Eotetranychus yumensis* (McG.), and the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.).

THE CITRUS RED MITE, *Metatetranychus citri* (McG.), in certain districts of southern California, appears to have developed a measure of resistance to the widely used acaricide ovex (supplied by The Dow Chemical Co., Seal Beach, Calif.). In initial field screening tests applications of 4,4′-dichloro-α-(trichloromethyl)benzhydrol, or FW-293 (supplied by Rohm & Haas Co., Philadelphia, Pa.) resulted in effective control of citrus red mite.

This paper shows the effectiveness of FW-293 in relation to the acaricides currently in use for control of citrus red mite and other mites injurious to citrus in this area.

Materials and Methods

All spray applications for these studies were made in commercial citrus groves. Conventional equipment was used for treatments for citrus red mite control on lemons in six groves at Corona in Riverside County, in one grove in San Diego County, and in two groves at Santa Paula in Ventura County; also on Valencia oranges at Anaheim and Tustin in Orange County, and on navel oranges at Corona and Riverside in Riverside County and at Redlands in San Bernardino County. Three lemon groves at Corona were used for tests with boom equipment. Spray-blower applications were evaluated in a lemon grove at Corona and in a navel orange grove at Redlands. Treatments for control of the citrus flat mite, *Brevipalpus lewisi* McG., included Valencia and navel oranges at Porterville and Exeter in the San Joaquin Valley, and tangerines at El Centro in the Imperial Valley. Two groves at Escondido were utilized for evaluation of this acaricide for control of the citrus bud mite, *Aceria sheldoni* (Ewing), on lemons.

Table I. Effectiveness of FW-293 Applied by Conventional Equipment for Control of Citrus Red Mite on Lemon Trees

Material	Formulation, %[a]	Actual Toxicant, Ounce/100 Gal.	Av. No. of Live Mites Per 32-Leaf Sample				
Grove A, Corona, Riverside Co., Treated April 8, 1954							
			Days after Treatment[b]				
			14	28	49	75	116
FW-293	15.0 EC	3	0.0	0.7	6.0	31.0	40.0
	15.0 EC	4	0.6	0.7	3.5	21.5	20.0
	18.5 WP	3	28.5	0.6	8.0	72.0	RT
	18.5 WP	4	11.5	0.4	4.0	72.5	RT
Demeton	21.2 EC	2	0.0	0.0	2.5	4.3	29.5
Ovex	50.0 WP	3	3.0	19.0	136.0	RT	
Neotran	40.0 WP	0.25					
Petroleum oil (light-medium)	...	1¾ gal.	0.0	11.3	18.0	105.0	217.0
Grove B, Corona, Riverside Co., Treated June 18, 1954							
			Days after Treatment[b]				
			22	63	79	123	253
FW-293	15.0 EC	6	1.5	0.9	8.0	13.6	48.5
	15.0 EC	12	1.0	0.4	7.1	4.3	17.2
	18.5 WP	6	1.0	2.3	30.0	65.0	105.0
	18.5 WP	4	73.5	2.0	35.0	145.5	RT
Demeton	21.2 EC	1	0.7	0.5	49.0	85.0	52.0
	21.2 EC	2	0.0	0.3	5.0	17.5	44.0
Grove C, Corona, Riverside Co., Treated November 3, 1955							
			Days after Treatment				
			194	215	242	257	
FW-293	18.5 EC	3	0.0	1.4	8.5	16.0	
	18.5 EC	6	0.0	1.5	1.1	4.3	
	18.5 WP	3	0.1	1.0	2.8	5.5	
	18.5 WP	6	0.0	1.2	5.8	7.5	
Demeton	26.1 EC	2	1.0	8.5	1.5	15.5	
	26.1 EC	3	1.0	10.4	1.6	8.5	
Grove D, Santa Paula, Ventura Co., Treated February 8, 1956							
			Days after Treatment				
			82	110	126	139	166
FW-293	18.5 EC	4.5	0.0	0.7	1.2	0.9	6.0
	18.5 WP	4.5	0.0	0.0	0.6	1.8	10.5
Demeton	26.1 EC	2.0	0.0	0.1	10.0	2.2	52.0
Ovex	50.0 WP	4.0	2.6	9.7	115.0	RT	
Aramite	15.0 WP	1.5					

Table I. Effectiveness of FW-293 Applied by Conventional Equipment for Control of Citrus Red Mite on Lemon Trees (Continued)

Material	Formulaton, %[a]	Actual Toxicant, Ounce/100 Gal.	Av. No. of Live Mites Per 32-Leaf Sample			
Grove E, Santa Paula, Ventura Co., Treated February 16, 1956						
			Days after Treatment[b]			
			54	74	118	171
FW-293	18.5 EC	4.5	0.0	1.0	0.4	275
Ovex	50.0 WP	4.0	11.0	83.0	RT	...
Aramite	15.0 WP	1.8				
Grove F, Rancho Santa Fe, San Diego Co., Treated October 17, 1955						
			Days after Treatment			
			182	226	245	275
FW-293	18.5 WP	3.0	4.2	9.0	37.6	760.0
	18.5 WP	6.0	0.0	0.0	0.2	3.8
Demeton	26.1 EC	2.0	0.0	0.0	0.0	3.8

[a] EC, emulsifiable concentrate; WP, wettable powder.
[b] RT, re-treated.

Table II. Effectiveness of FW-293 Applied by Conventional Equipment for Control of Citrus Red Mite in Five Orange Groves[a]

Material	Formulation, %[b]	Actual Toxicant, Ounce/100 Gal.	Av. No. of Live Mites per 32-Leaf Sample				
			Grove A after 144 days	Grove B after 279 days	Grove C after 164 days	Grove D after 293 days	Grove E after 124 days
FW-293	15.0 EC	3	3	2	7	1	5
	15.0 EC	6	0	1	8	0	2
	18.5 WP	3	21	6	9	5	12
	18.5 WP	6	4	3	7	2	5
Demeton	21.2 EC	1	10	98	2	3	12
	21.2 EC	2	4	45	1	2	17
Ovex	50.0 WP	4	142	..	..	..	..
Petroleum oil (light-medium)	...	1 3/4 gal.	...	25	..	..	..

[a] Grove A (Valencia oranges, Anaheim) treated May 6, 1954. Grove B (Valencia oranges, Tustin) treated October 15, 1954. Grove C (Navel oranges, Corona), treated March 22, 1955. Grove D (Navel oranges, Riverside) treated September 20, 1954. Grove E (Navel oranges, Redlands) treated April 6, 1956.
[b] EC, emulsifiable concentrate; WP, wettable powder.

Table III. Effectiveness of FW-293 Applied by Boom Equipment for Control of Citrus Red Mite at Corona

Material	Formulation, %[a]	Actual Toxicant, Lb./Acre	Av. No. of Live Mites per 32-Leaf Sample				
Grove A, Treated May 17, 1955, at 1500 Gal./Acre							
			Days after Treatment[b]				
			30	45	80	178	202
FW-293	18.5 EC	2.25	0.0	0.1	1.0	14.0	7.5
Demeton	26.1 EC	1.25	0.1	0.1	1.5	8.0	24.5
Ovex	50.0 WP	4.0	1.5	3.0	25.3	RT[b]	...
Aramite	15.0 WP	3.0	0.0	0.1	10.0	RT	...
Grove B, Treated November 11, 1955, at 1500 Gal./Acre							
			Days after Treatment				
			70	146	164	178	
FW-293	18.5 EC	3.7	0.0	0.0	0.0	0.1	
	18.5 WP	3.7	0.0	0.0	0.8	0.5	
Demeton	26.1 EC	1.25	0.1	0.0	8.4	32.0	
Aramite	15.0 WP	2.4	7.1	23.0	RT	...	
Ovex	50.0 WP	4.0	8.0	20.0	RT	...	
Grove C, Treated March 1, 1956, at 1500 Gal./Acre							
			Days after Treatment				
			62		137		
FW-293	18.5 EC	3.0	0.0		5.0		
Demeton	26.1 EC	1.25	0.1		94.0		

[a] EC, emulsifiable concentrate; WP, wettable powder.
[b] RT, re-treated

Conventional sprays were applied by means of orchard spray rigs equipped with high-pressure reciprocating-type pumps and manually operated spray guns. A tower was used where adequate coverage was not readily obtained by spraying from the ground. Applications were made at 1500 to 2000 gallons per acre—the rate depending on the size of the trees. Boom-spray applications were made with an oscillating boom sprayer equipped with a high-pressure centrifugal pump. Spray-blower applications were made by means of a fishtail type, high air-volume blower equipped with spray pump capable of discharging spray into the air stream in the fishtail under 300 pounds' pressure. The gallonage of spray applied per acre by boom and spray-blower equipment varied according to the tree size. Amounts are indicated in the tables of results.

Plots treated for citrus red mite control consisted of eight trees each, with adequte buffer rows to allow for spray drift. Each treatment was applied to two plots in each grove. Citrus red mite populations were evaluated by counting the adult mites on 32 leaves on each of the eight trees in each plot, as described by Jeppson (*1*). Results are reported as average number of mites per tree (32-leaf sample). To evaluate populations of citrus flat mite, two 1-inch square areas were examined on each of eight fruits per tree, eight trees per plot, by means of a linen counter. Results are reported as average number of mites per square inch of fruit surface. Evaluations of populations of the citrus bud mite were made by examining five buds on each of 15 new-growth terminals from each of eight trees per plot. Results are reported as percentages of buds infested.

Results

The rates of repopulation of citrus red mite in six lemon groves treated with conventional spray equipment are reported in Table I.

The effectiveness of conventional spray applications of FW-293 as compared with that of similar applications of demeton, ovex, or petroleum oil for control of the citrus red mite in five orange groves is reported in Table II. Citrus red mite population trends following boom applications of FW-293 in three lemon groves are reported in Table III. Results of spray-blower treatments in a lemon grove at Corona and a navel orange grove at Redlands are reported in Table IV. The relative effectiveness of FW-293 and Chlorobenzilate for control of the citrus flat mite on oranges and tangerines, as indicated by tests in three groves, is reported in Table V. The degree of control of citrus bud mite obtained from applications of FW-293

Table IV. Relative Effectiveness of FW-293 and Demeton Applied by Spray-blower Equipment for Control of Citrus Red Mite

Material	Emulsifiable Concentrote, %[a]	Actual Toxicant, Lb./Acre	Av. No. of Live Mites per 32-Leaf Sample					
Grove A (Lemons, Corona), Treated July 15, 1954, at 300 Gal./Acre								
			Days after Treatment					
			36	60	106	116	180	218
FW-293	15.0	1.5	0.1	0.9	0.7	0.2	2.9	27.5
Demeton	21.2	0.62	0.0	1.5	1.0	2.5	0.5	62.0
Grove B (Navel Oranges, Redlands), Treated April 4, 1956, at 600 Gal./Acre								
			Days after Treatment					
			15		82		107	
FW-293	18.5	2.75	0.0		0.0		7.3	
Demeton	26.1	1.25	0.0		7.0		15.5	

[a] EC, emulsifiable concentrate.

Table V. Relative Effectiveness of FW-293 and Chlorobenzilate for Control of the Citrus Flat Mite on Orange and Tangerine Trees[a]

Material	Formulation, % Wettable Powder	Actual Toxicant Ounce/ 100 Gal.	Av. No. of Live Mites per Sample (1 Sq. In. of Fruit Surface)	
Grove A, Conventional Spray Application June 16, 1955, at 2250 Gal./Acre				
			Aug. 3	Oct. 12
FW-293	18.5	3.0	0.00	0.00
Chlorobenzilate	25.0	4.0	0.00	0.13
Check[b]	...	...	0.88	0.63
Grove B, Boom-Spray Application July 15, 1955, at 1000 Gal./Acre				
			Aug. 3	Oct. 12
FW-293	18.5	3.0	0.00	0.00
	18.5	1.9	0.00	0.00
Chlorobenzilate	25.0	4.0	0.00	0.30
	25.0	3.0	0.00	0.19
Check[b]	...	...	7.22	...
Grove C, Conventional Spray Application November 2, 1955, at 1500 Gal./Acre				
			Pre-treatment	Nov. 23	Dec. 3
FW-293	18.5	0.75	111.0	1.00	0.00
Chlorobenzilate	25.0	1.0	64.5	2.63	0.19
	25.0	2.0	43.5	0.88	0.00
Ovex	50.0	4.0	20.0	4.50	0.88

[a] Grove A (Navel oranges) at Exeter. Grove B (Valencia oranges) at Porterville. Grove C (Tangerines) at El Centro.
[b] Check treatment, a phosphate-type insecticide which was ineffective against this mite.

Table VI. Effectiveness of FW-293 in Relation to Chlorobenzilate and Petroleum Oil, Applied by Conventional Equipment for Control of Citrus Bud Mite on Lemon Trees at Escondido

Material	Formulation % Wettable Powder	Actual Toxicant Ounce/100 Gal.	% Buds Infested		
Grove A, Treated April 15, 1954					
			June 22		July 7
FW-293	18.5	9	54		RT
Chlorobenzilate	25.0	2	0		10
Petroleum oil (light-medium)	...	1.75 gal.	..		32
Grove B, Treated May 10, 1955					
			June 22	July 12	Aug. 18
FW-293	18.5	6	5	16	52
FW-293	18.5	3	0	2	5
Chlorobenzilate	25.0	2			
Chlorobenzilate	25.0	4	0	4	10
Petroleum oil (light-medium)	...	1.75 gal.	0	6	35

in two lemon groves as compared with that from petroleum oil and Chlorobenzilate is reported in Table VI.

Discussion

The citrus red mite populations in the Corona area appear to have developed some degree of resistance to ovex; therefore, this treatment does not serve as an indicative control for tests reported in Tables I, (Groves A-C) and III. However, demeton and petroleum oil may be used as a basis for evaluating the effectiveness of the material under study. Results of the conventional spray applications made in April and June, 1954 (Table I, Groves A and B), indicate that the emulsifiable formulation was more effective than the wettable-powder formulation, which caused injury to young citrus leaves in these two tests. A new wettable-powder formulation mitigated the injury and proved to be more effective than the initial formulation and as effective as the emulsifiable formulation (Table I, Grove D and Table III, Grove B). The emulsifiable-concentrate formulation of FW-293 applied at 4 to 6 ounces of the actual material per 100 gallons of spray was as effective in controlling this mite as 2 ounces of demeton, and more effective than a petroleum oil spray application using $1^3/_4$ gallons of oil per 100 gallons. At Santa Paula, FW-293, used at 4.5 ounces per 100 gallons of spray, resulted in measurably better control than 2 ounces of demeton and was considerably more effective than a combination of ovex and Aramite applied at 4 and 1.5 ounces per 100 gallons, respectively (Table I, Grove D).

Applications of 2.25 pounds of FW-293 per acre in May and of 3.7 pounds in November as an emulsifiable-concentrate formulation by means of boom equipment, compared well in control of citrus red mite with similar applications of demeton applied at 1.25 pounds per acre (Table III). The boom applications of FW-293 were more effective than regular dosages of either ovex or Aramite under the conditions of the experiment. Spray-blower applications of FW-293 employing 300 or 600 gallons of spray per acre resulted in control of citrus red mite comparable to that of commercial dosages of demeton.

Applications of FW-293 to Valencia oranges at Anaheim and Tustin, and to navel oranges at Corona and Riverside, resulted in relatively low populations of the citrus red mite for 144 to 293 days (Table II). In the grove at Anaheim citrus red mite populations on the ovex-treated plots were high at the close of the test. At Tustin, demeton at 2 ounces and petroleum oil at $1^3/_4$ gallons were less effective than FW-293 when applied at 3 ounces in either a wettable-powder or an emulsifiable-concentrate

formulation. At Redlands, the FW-293 applications resulted in as effective control as the standard dosage of demeton.

In experiments conducted in the San Joaquin Valley, FW-293 was more effective than either ovex or Chlorobenzilate in controlling the citrus flat mite (Table V). Ovex is not an effective treatment for this mite, but Chlorobenzilate has resulted in effective reduction in mite populations (*2*).

FW-293 was less effective than petroleum oil or Chlorobenzilate in the control of citrus bud mite (Table VI), but when a combination of FW-293 and Chlorobenzilate was used the treatment was more effective than Chlorobenzilate alone (Table VI).

In limited field trials, FW-293 resulted in good initial reduction of populations of the six-spotted mite, *Eotetranychus sexmaculatus* (Riley), the Yuma mite, *E. yumensis* (McG.), and the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.). As reinfestations of these mites did not occur on the test plots before the groves required re-treatment for some other pest, data on the relative effectiveness of FW-293 with standard treatments are not available.

Literature Cited

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PESTICIDE RESIDUES

Field Persistence of the Acaricide 4,4′-Dichloro-alpha-(trichloromethyl)-benzhydrol (FW-293) on and in Mature Lemons and Oranges

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Residues of the new acaricide, 4,4′-dichloro-α-(trichloromethyl)benzhydrol, or FW-293, were determined on and in lemons and oranges and in dried citrus cattle feed resulting from these fruits. The longevity of these residues is illustrated by the half-life values of 170 to 350 days for Valencia oranges and 120 to 150 days for lemons. Comparisons of the magnitudes of the residues obtained simultaneously by three methods indicate little if any metabolic or other degradation of FW-293 residues *in situ*. Negligible amounts of FW-293 were found in edible portions of the fruit. The peel retained approximately 30% of its FW-293 residues after being processed into dried citrus cattle feed.

THE COMPOUND, 4,4′-dichloro-α-(trichloromethyl)benzhydrol, or FW-293, is a general acaricide against several mites and is proving useful in the control of the citrus red mite, *Metatetranychus citri* (McG.) and the citrus flat mite, *Brevipalpus lewisi* McG., on lemons and oranges in California (*4*). The present paper is concerned with the magnitudes of persisting residues of this acaricide in lemons and navel oranges treated in the field with commercial formulations.

Two semispecific analytical methods suitable for determining the magnitudes of residues of FW-293 on and in citrus tissues have been discussed (*3,5*). The first method (chloroform method) determines chloroform released quantitatively from FW-293 treated with strong alkali; the second method (ketone method) determines the 4,4′-dichlorobenzophenone moiety of the parent molecule as liberated by mild alkaline treatment or as deposited in the fruit tissues by metabolic or other degradation *in situ*. Simultaneous scrutiny, by both analytical methods, of fruit samples collected at successive intervals after application, should therefore afford insight into degradative pathways of residues persisting within the treated fruits. For example, if the chloroform-type assays consistently diverged from the benzophenone-type assays with increasing posttreatment time, *in situ* degradation of the parent molecule would be proved.

On the other hand, if both types of assay conformed in decreasing the magnitudes of residues found, volatility or other losses of the entire parent molecule would be indicated. Finally, if both methods showed that the persisting residues were not decreasing with time, there could be little doubt that the parent deposits or residues were resisting mechanical dislodgment and metabolic, or other, degradation.

To supplement evaluations of these three possible types of residue behavior, a third analytical method was also employed. Determinations were made on parallel aliquots of the stripping solutions by means of the chloroform method and by the combustion total organic chloride method (*7*); additional key determinations were made by the more complicated ketone method on other parallel aliquots of the stripping solutions.

Data from all three methods agree in that they indicate that FW-293 residues on and in lemons and Valencia oranges deviate from the previously established (*1,2*) degradation and persistence behavior of other acaricide residues in citrus fruits. FW-293 residues persist without significant change for remarkably long periods after establishment as residues.

Materials and Methods

Mature Valencia orange trees were sprayed on June 28, 1955, with either 1.6 pounds of a 25% wettable-powder formulation of FW-293 per 100 gallons of water or with 1.6 pints of a 25% emulsifiable-concentrate formulation of FW-293 (2 pounds per gallon) per 100 gallons of water. Applications were made as conventional sprays, using a high-pressure reciprocating pump and manually operated spray guns. Final sprays were applied at the rate of approximately 1500 gallons per acre. Mature lemon trees were sprayed similarly using the same spray concentrations on December 12, 1955. Mature navel orange trees were similarly treated January 5, 1956.

Mature orange fruit samples for assay of residues were collected 1, 5, 11, 15, 24, 43, 78, and 103 days after treatment. Mature lemon fruit samples for assay were collected 0, 10, 17, 24, and 31 days after treatment. Eight fruits (two from