Formulation and Application of Methoxychlor for Elm Bark Beetle Control

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USDA FOREST SERVICE RESEARCH PAPER NE-283
1973

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MANUSCRIPT RECEIVED FOR PUBLICATION 21 SEPTEMBER 1973

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ABSTRACT

American elm trees, *Ulmus americana* L., were sprayed with different formulations of methoxychlor by mistblower, hydraulic sprayer or helicopter. Twig-crotches were collected from sprayed trees for GLC assay and *Scolytus multistriatus* (Marsham) bioassay. Hydraulic deposits were heaviest but the mistblower was more efficient in terms of amount deposited per pound of methoxychlor sprayed. Helicopter deposits were light on lower branches but were comparable to mistblower and hydraulic deposits in tops of trees, where protection is needed most.

Federal laws regulating use of DDT have forced arborists and city foresters to seek other materials to protect elms from smaller European elm bark beetles, *Scolytus multistriatus* (Marsham), principal vectors of Dutch elm disease fungus. Methoxychlor was shown to be effective and has been approved for this purpose. However, arborists need more information on the effectiveness of methoxychlor formulations when applied by mistblower, hydraulic sprayer, or helicopter. In studies of DDT formulations (Whitten 1945, Matthysse et al. 1954), it was suggested that white oil might increase insecticide deposits on tree tops and Whitten reported that quick-breaking emulsions may be preferable to more stable ones, but quantitative data were not given. Although formulations with HAN solvents damage paint finishes less than xylene, and formulations containing 32% methoxychlor cost less to ship and handle, the effectiveness of these formulations has not been adequately tested. Therefore, in 1970 the Forest Service conducted an experiment in cooperation with state, city and private organizations to compare the amounts of methoxychlor deposited on elm twigs by spraying with different formulations and types of equipment.

METHODS AND PROCEDURES

Location and Treatments

The experiment was conducted in Ohio and Massachusetts. All trees in Ohio and about half of those in Massachusetts had been sprayed previously with DDT but none had been sprayed with methoxychlor for at least 4 years. Ohio trees ranged in height from 31 to 69 ft. (average 51 ft.); Massachusetts trees ranged from 30 to 90 ft. (average 64 ft.), and, in general, had fewer branches in the lower part of the crowns.

A John Bean Rotomist[1] 100-G mistblower with No. 5 discs/5 hole whirlplates calibrated at 2 gal. per minute was used in Ohio and a Hardie Aero-Mist L-80-A mistblower with 2 tangential type T No. 1120M nozzles calibrated at 1.5 gal. per minute was used in Massachusetts.

John Bean Royal hydraulic sprayers were used in both areas. All formulations in Ohio were applied at about 25 gal. per minute with a No. 16 disc. In Massachusetts, formulations 2 and 4 were applied at 29 gal. per minute with a standard Bean shade tree gun and formulations 1, 3, and 5 were applied at 23 gal. per minute with a No. 10 disc (table 1).

In Ohio, the helicopter sprayed from 15 to 25 ft. above trees with 20 D6 nozzles on a 32 ft. boom at 45 psi. In Massachusetts, the helicopter sprayed from 10 to 20 ft. above trees at 0 to 5 mph with a total of 27 D8 nozzles with No. 45 cores on 2 lateral 10 ft. booms and 1 aft 8 ft. boom at 45 psi. boom pressure. Methoxychlor concentration in spray solutions was 2 percent for hydraulic and 12.5 percent for mistblower. In Massachusetts, formulations 1 and 2 were applied by helicopter at 12.5 percent but 3, 4, and 5 were applied at 8 percent due to errors in mixing. All formulations applied by helicopter in Ohio were at 12.5 percent. The amount of methoxychlor sprayed at a tree was estimated by either timing or metering

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Table 1.—*Formulation specificatons of methoxychlor sprayed in Ohio and Massachusetts, Spring 1970*

Formulation no.	Type of solvent	Type of emulsifier	Percent methoxychlor	Additives
1	Xylenes[a]	Q.B.[b]	25	—
2	Xylenes	S.B.[b]	25	—
3	Xylenes	Q.B.	32	—
4	Xylenes	Q.B.	25	8% white oil
5	Heavy aromatic naphthalenes (HAN)	Q.B.	25	—

[a]Boiling range 270-310°F.; KB 96.
[b]Q.B. separation <10 min; S.B. >10 min.

the spray application. Trees were sprayed from 18 to 30 April 1970.

Design and Sampling

The experimental design is a repeated measure two-factor design replicated at two locations. The 14 treatments were randomly assigned to 14 plots in each location, with each plot containing five trees. Test variables were methoxychlor deposits and bark beetle responses on twigs from 12 sectors of each tree. The crowns of trees were marked off into 12 sectors (three levels and four quadrants). Five twigs were collected from each sector for chemical analysis. An additional sample of 10 twigs per sector was collected for bioassay from 26 trees which had not been previously sprayed with DDT. Trees were sampled twice, once from 6 to 21 days after spraying and again from 152 to 172 days after spraying.

Chemical Assay

Samples were analyzed on a Varian Aerograph[1] chromatograph equipped with an Ni-63 electron capture detector. A ⅛-in. O.D. glass column, 6 ft. long, packed with 5 percent DC-11 on 70 to 80 mesh Aeropack 30 with a nitrogen exit flow of 30 to 35 ml./min. was used. Relevant temperatures were: injection port 245°C., column 235°C., detector 375°C. Retention time of methoxychlor was about 4 minutes.

Circular patches (4.5 mm^2.) were cut from crotches of twigs with sharpened tubing. Methoxychlor was dissolved from five patches of a sector by shaking them in a nanograde hexane for about 15 minutes. When necessary, samples were diluted with up to 110 ml. of hexane to bring the amount of methoxychlor injected within linear range of the detector. Three μl. of hexane-methoxychlor extract were injected into the chromatograph. After every fourth sample, methoxychlor standards were injected. The heights of sample peaks were compared with standard peaks to determine the methoxychlor concentration in samples.

Most methoxychlor deposits on elm twigs ranged from 0.1 to 1.0 μg./mm^2. (ca. 200 to 2,000 ppm). Because this concentration is high, a complex sample preparation procedure was not necessary. The procedure was sufficient to distinguish biologically significant differences in amounts of methoxychlor. However, the assay overestimated light deposits and underestimated heavy deposits. Calibration studies show that recovery of methoxychlor added to twigs was about 133 percent at 0.10 μg./mm.^{2}, 80 percent at 0.75 μg./mm.^{2}, and 75 percent at 100 μg./mm.^{2}.

Bioassay

A bioassay described by Barger et al. (1970) was used to evaluate feeding rates of beetles. A beetle was caged in a small perforated brass cylinder on the crotch of an elm twig and allowed to feed for 24 hours. A twig was considered protected if a beetle did not feed to the xylem.

Analysis

For each treatment (combination of formulation, equipment, location), means of methoxychlor deposits were plotted against variances. There was a consistent relationship between $\overline{X}$ and S^2 for treatments applied by the same equipment. Because of this relationship, observations of methoxychlor deposits were transformed to logarithm Y to stabilize variances for ANOVA. In addition, the relationship for hydraulic treatments was different from treatments by mistblower and helicopter. Therefore, data from helicopter and mistblower treatments were analyzed together and a separate analysis was run for the treatment with hydraulic spraying.

The association between chemical assays and bioassays was approximated graphically. Since the two assays cannot be conducted on the same twigs, amounts of methoxychlor on bioassayed twigs were estimated by the mean methoxychlor residue on the other random sample of twigs from the same sectors. Beetle feeding failure on twigs within a range of estimated amounts of methoxychlor were averaged and plotted at the midpoint of this range.

Because negligible spray deposits resulted from helicopter treatments in Ohio, none of the data from these trees were analyzed. Because most trees in Massachusetts had too few twigs in the lower sections, only data from the top and middle levels of these trees were included in the analysis.

RESULTS AND DISCUSSION

Important parameters of spray application are: amount and variation in deposits; persistance of deposits; and ability of insecticide to prevent feeding. Insecticides should be highly toxic to beetles and should be deposited where beetles are likely to contact them. There should be uniform coverage, each twig with just enough insecticide to deter feeding. Toxic residues should remain on twigs for several months.

Analysis showed that the significant factors in the experiment were type of spray equipment and level in tree.

Amounts and Variation in Deposits

Amounts of methoxychlor deposited differed with the method of application. The difference was most evident at the middle and lower levels of tree crowns. Deposits on middle and lower levels of trees sprayed by mistblower or hydraulic sprayer were about twice as heavy as deposits on top (table 2).

Helicopter deposits, however, were more than twice as heavy on top as on the middle. On treetops, which are considered most susceptible to beetle attack (Wolfenbarger and Buchanan 1939), the three types of equipment resulted in about equally heavy deposits with the doses used in this study.

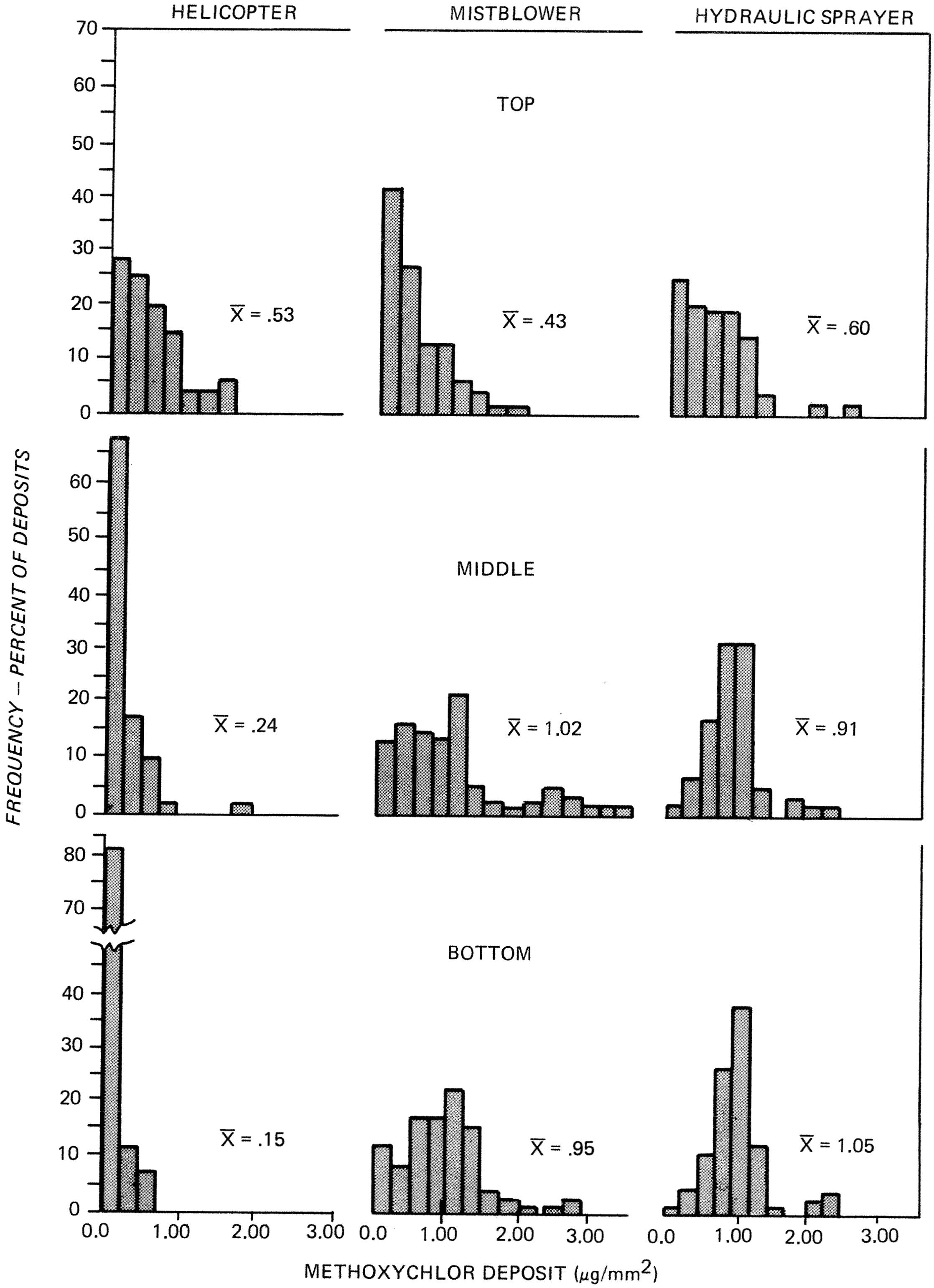
The different types of spray equipment required the application of different doses to the trees. The average dose per tree was 4.2 lb. for the hydraulic sprayer, 1.9 lb. for the mistblower, and 1.6 lb. for the helicopter even though the average tree heights were about the same: 52 ft., 57 ft., and 50 ft., respectively. Comparing the amount of methoxychlor de-

Table 2.—*Average methoxychlor deposits detected on elm twig crotches after spraying with mistblower, hydraulic sprayer or helicopter*

Type of equipment	Average μg methoxychlor/mm.^{2} of bark					
	Initial samples from			Final samples from		
	Top	Middle	Bottom[a]	Top	Middle	Bottom[a]
Mist	0.43	1.02	0.95	0.16	0.45	0.54
Hydraulic	.60	.91	1.05	.21	.44	.57
Helicopter	.53	.24	.15	.14	.10	.06
Mist versus helicopter	NS	**	—	—	—	—

NS - Not significant at .05 level of probability.
** - Significant at .01 level of probability.
— - No test completed.
[a]Values on bottom levels not included in averages or statistical analyses because many trees had few twigs on bottom levels.

Figure 1. — Frequency distribution of initial methoxychlor deposits on three levels of elm crowns, sprayed by helicopter, mistblower, and hydraulic sprayer.



posited on a tree with the amount sprayed at a tree, the mistblower is clearly the most efficient. Comparing the amount deposited on treetops with the amount sprayed, the helicopter is the most efficient.

Although spray operators were skilled and worked carefully, uneven coverage was common with each type of equipment. Methoxychlor deposits varied widely among tree sectors. Often there was a 10X difference between the lightest and heaviest deposits within the crown of a single tree and a 2X difference between the lightest and heaviest deposits on trees sprayed at the same time by the same operator, with the same equipment and formulation. Only a small part of deposit variability can be explained by differences in tree size. Doses depended on tree size; an operator sprayed a tree until he estimated it was adequately covered. Amounts of methoxychlor sprayed at trees varied from 1.1 to 11.2 lb., depending on tree size, equipment, and operator.

The frequency distribution shows the variation in deposits for each type of equipment on each level of the trees (fig. 1). The best distribution of deposits was on the bottom level of hydraulically sprayed trees. Most twigs on this level were consistently covered with relatively heavy amounts of methoxychlor. Seventy-six percent of the twigs had between 0.75 and 1.50 μg./mm.^{2} of methoxychlor.

A comparison between deposits at the middle level by mistblower and by hydraulic spraying shows that variances differed although average deposits on trees sprayed by both types of equipment were about the same, 1.02 and 0.91 μg/mm.^{2} On mistblower-sprayed trees about 3X as many twigs were covered with less than 0.25 μg./mm.^{2} as on hydraulically sprayed trees.

The variability of deposits on treetops was similar for each type of equipment. Hydraulic and helicopter deposits were slightly heavier than mistblower deposits. However, for all 3 types of equipment at least 25 percent of the twigs had deposits of less than 0.25 μg./mm.^{2}

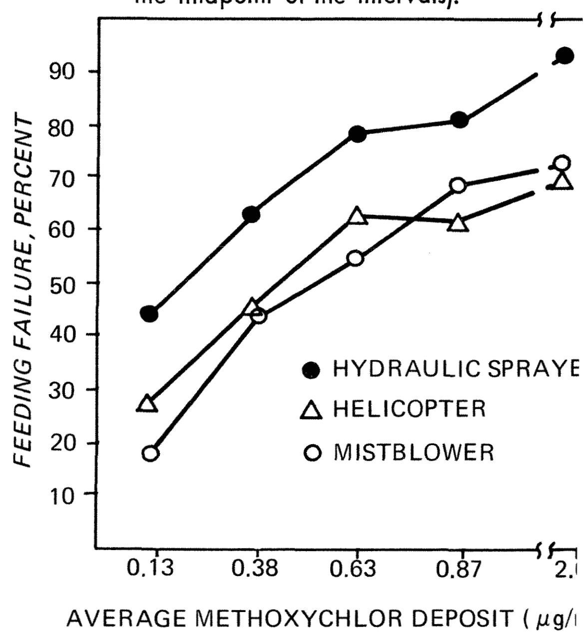
Persistence

In general, methoxychlor deposits from all formulas sprayed by each type of equipment in both areas weathered at the same rate (table 2). Deposits after 5 months depended primarily on initial deposits. After 5 months, residual methoxychlor was from one-third to one-half the initial amount.

Feeding Prevention

Beetle feeding was inversely proportional to amounts of methoxychlor on twigs. In a study of methoxychlor effectiveness (Barger et al. 1972), about 90 percent of elm bark beetles were deterred from feeding by 1.1 μg./mm.^{2} of methoxychlor. About 50 percent were deterred by 0.5 μg./mm.^{2} Toxicity of deposits by mistblower and helicopter were similar in this study (fig. 2). However, deposits from hydraulic sprayers appeared to be 1.5 times as toxic. One possible explanation for the greater toxicity of hydraulic-sprayer deposits is uniform coverage. All twigs within a sector were covered with about the same amount of insecticide. On the other hand, mistblowers and helicopters atomize spray, and methoxychlor deposits vary among twigs. Some twigs may have heavy de-

Figure 2. — Association between beetle feeding and methoxychlor deposits from mistblower, helicopter, and hydraulic applications. Average bark beetle feeding failure rate within intervals of estimated methoxychlor deposits (plotted at the midpoint of the intervals).



posits and others light deposits, and beetles may feed on the lightly covered twigs.

The best equipment for spraying elms depends on job requirements. Helicopter applications offer treetop coverage equal to that achieved by ground equipment, but at lower doses and with greater speed. However, helicopters are so sensitive to wind that in some areas few days are suitable for spraying.

Hydraulic sprayers have the advantages that deposits are heavier and more uniform than with other equipment; they are maneuverable; and they are least sensitive to wind. However, hydraulic sprayers use more than twice as much insecticide as helicopters and require more time.

Mistblowers are intermediate. Their speed, maneuverability, sensitivity to wind, amount of insecticide used, and amount deposited are between those of hydraulic and helicopter applications.

SUMMARY AND CONCLUSION

When used as recommended, the three types of spray equipment produced considerably different deposits. Deposits from the hydraulic sprayer were heaviest and most uniform, but it used twice as much insecticide as the mistblower or helicopter. Average deposits applied by mistblower were almost as heavy as those of the hydraulic sprayer, but deposits were more variable. Although average deposits from helicopter spraying were about half as heavy as those from the mistblower or hydraulic sprayer, deposits on treetops were about the same for all three types of equipment. Most methoxychlor applied by helicopter was on treetops, whereas most applied by mistblower or hydraulic sprayer was on the lower crown. Regardless of the equipment, most treetop deposits were less than 0.5 μg./mm.^{2} Protection should be best on the tops of trees because beetles feed more there than at lower levels.

The five formulations resulted in about the same deposits. If real differences existed among formulations these differences were small compared to differences among plots and trees.

Because weathering reduced methoxychlor deposits to one-third to one-half initial amounts, protection appears to be marginal after 5 months.

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ACKNOWLEDGMENTS

The authors thank the following contributors: American Oil Company; Michlin Chemical Company; Davey Tree Expert Company; Ag Helicopters, Inc.; Lowden Tree Specialists, Inc., Plymouth Copters, Inc.; Concord, Mass., Dept. of Natural Resources; Cleveland, Ohio, Division of Shade Trees; Shaker Heights, Ohio, Public Service; Mass. Audubon Society; Mass. Dept. of Natural Resources —Bureau of Pest Control; and University of Mass. Shade Tree Laboratory.

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