Plantation Research: VII. Experimental Aerial Applications of Methoxychlor for Control of White Pine Weevil (<u>Pissodes strobi</u>) in Ontario, 1972

by

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Aircraft Guidance System

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INTRODUCTION

Water-based formulations of methoxychlor insecticide as wettable powder or emulsifiable concentrate have been effective for control of the white pine weevil (*Pissodes strobi* Peck) when applied by high-volume hydraulic sprayer (DeBoo and Campbell 1971, 1972). Population reductions of 90% to 100% have been achieved at rates of 1 to 2 lb active ingredient (a.i.) in approximately 100 gal water/acre. Aerial applications of methoxychlor in Ontario from 1969 to 1971, however, have not provided satisfactory control. Howse and Sippell (1971) have reported that rates of 2 to 3 lb in 2 gal water/acre reduce weevil attack by only 56% to 74%.

In view of the urgent requirements for chemical control of this important plantation pest, an experimental aerial spray program was inaugurated during 1972 in southern Ontario to determine:

(1) the efficacy of methoxychlor for control of the weevil in high-value white pine (*Pinus strobus* L.) plantations;

(2) the importance of spray volume and formulation (e.g., water, oil) using conventional boom and nozzle emission equipment;

(3) the consequence of several adjuvants in aqueous spray solutions to minimize drift and increase deposit.

The program was conducted after consultation and discussion with staff of the Ontario Ministry of Natural Resources and the Great Lakes Forest Research Center. Staff of these agencies, the Chemical

Control Research Institute, and representatives of the chemical industry actively participated in the field work. The aerial applications described in this report constituted preliminary trials aimed at the eventual derivation of sound operational control methods. The exclusion of certain manufactured products does not imply rejection, nor does the mention of other products imply exclusive endorsement by the Canadian Forestry Service.

MATERIALS AND METHODS

Plantation Survey

Preliminary estimates of weevil injury were made in white pine plantations by staff of the Coldwater and Angus offices of the Ontario Ministry of Natural Resources during the winter of 1971-72. Compilations included percentages of trees weeviled, tree size and age, plantation acreages and locations within the Simcoe County reforestation areas. These reports provided the basic information necessary for the selection of treatment blocks qualifying under the following requirements:

(1) 10% or greater leader injury to trees during 1971 for some assurance of similar populations of the insect during 1972;

(2) trees not in excess of 25 ft in height for accuracy in visual assessments of leader condition from the ground following treatment;

(3) plantation blocks of 20 acres or more for replication of treatments.

This basic information, in turn, was used in conjunction with detailed plantation compartment maps to pinpoint locations for more intensive observations. These second-phase surveys were conducted from April 21 to May 1 jointly by staff of O.M.N.R., C.C.R.I., and G.L.F.R.C. Each priority plantation compartment was visited and transects were established for accurate appraisals of tree-top condition. On this basis, a total of 15 plantations on more than 580 acres were selected for the establishment of both spray treatment and untreated check plots.

Treatment Areas

The plantations selected for the spray program were located in the townships of Tay, Medonte, Flos, Oro, Innisfil, and Essa, to the north and south of the city of Barrie (Figure 1). White pine content in the selected areas was approximately 40% to 75% of the standing trees, the plantations being mostly mixtures of this species (in alternate rows and strips) with red pine (*P. resinosa* Ait.) and occasionally white spruce (*Picea glauca* (Moench) Voss) and larch (*Larix* spp.). Large hardwoods usually were found bordering these old-field plantations. These obstacles, and others such as hydro and telephone lines were duly noted as hazard areas for the pilot of the spray aircraft. Larger plantations (e.g., 100 acres or more) were occasionally divided into two or three treatment blocks of from 20 to 30 acres. A total of 16 spray blocks and four untreated check areas were established for the experiments. Acreages, tree heights and ages, and O.M.N.R. compartment designations are given in Table I. Weevil population levels, as expressed by the incidence of leader attack during 1971, ranged from 9% to 32% at the selected locations.

Methoxychlor Spray Formulations

All spray formulations conformed to two key requirements:

(1) total active ingredient of the applied insecticide was set at 2.5 lb/acre;

(2) spray mixture volumes applied were at either 2 or 4 gal/acre.

Sprays were mixed as shown in Table II. The emulsifiable concentrate formulation of methoxychlor was formulated at 2.4 lb a.i./gal by

Niagara Chemicals and was the same as supplied for the operational control program in Ontario, while the technical grade was obtained from DuPont Canada Ltd., the North American manufacturer. Water was obtained from the City of Barrie supply, and No. 2 fuel oil from a local Texaco bulk dealer. Other spray ingredients were supplied by chemical manufacturers and distributors listed in the Acknowledgements section of this report. All sprays were calculated in Imperial liquid measure.

Application Equipment and Field Operation Facilities

The aircraft used for this experimental spray program was a Piper Pawnee 235 fitted with a conventional boom and nozzle emission system (Figure 2). Nozzles for most applications were Spraying Systems Teejet Nos. D6 and D8 with No. 45 discs (Figure 3). From 27 to 29 of these nozzles were used depending upon volume requirements (i.e., 2 or 4 gal/acre, respectively). Delavan Dela-Foam "A" nozzles (Figure 4) were fitted to the boom for the methoxychlor/Fomark applications. A total of 22 Delavan nozzles (with 1505-81 metering discs) were spaced at approximately 18-inch intervals along each wing of the aircraft.

All application rates were calibrated and checked either at the Barrie Airport or in a 30-acre plantation at the Orr Lake Forest, approximately 14 miles northwest of Barrie. Pump pressure ranged from 35 to 40 psi for effective swath widths of 50 ft at elevations of from 5 to 20 ft above tree tops depending upon the occurrence of obstacles as mentioned previously. Flying speed was about 90 mph.

The C.C.R.I. experimental hydraulic sprayer (DeBoo and Campbell 1971, 1972) was utilized to load the aircraft (Figure 5). The incorporation of the Brooks flowmeter into this sprayer system was a very useful addition for accurate metering of spray mixture volumes. Flow rate was estimated at 10 gpm. Associated spray preparation equipment included a Lutz electric drum transfer pump and a "Lightnin" high-speed mixer (Figure 6).

All mixing of chemical sprays took place within a temporary storage compound/laboratory trailer site located near the aircraft tie-down pad at the airport (Figure 7). A 500-gal capacity tank mounted on a dual-axle utility trailer was used for water storage. Meteorological equipment, including a tower-mounted anemometer, also was situated at this location. The airport management provided an electrical hook-up for the operation of lights and power equipment. A telephone was installed in the trailer for communication with field staff by vehicle-mounted mobile phone, and walkie-talkies were used for short-distance communications within spray areas. Vehicles for transportation of field survey and/or spray crews were provided by all three government agencies involved in the program.

Project Staff

Mixing of sprays, adjustments of nozzles, loading and maintenance of the aircraft were duties assigned to one C.C.R.I. staff member and the pilot. Occasionally, technical representatives from the chemical industry assisted in these operations. The crew assigned to the field during the spray applications included one from C.C.R.I. and from two to four members of the Coldwater office, O.M.N.R.

The pilot assigned to the project was experienced in agricultural spraying operations, and also had previous experience in an experimental forest spray program. All other staff were familiar with forest insect control methodology and/or plantation management. The project thus required only minimal instruction while utilizing the expertise of all associated personnel.

Experimental Design

A total of 20 plantation blocks ranging in size from 20 to 64 acres were selected randomly as either spray treatment or untreated check replicates for use in the randomized complete block design. All but two spray treatments were replicated twice; the untreated check was composed of four replicates (Table I). Distances between replicates of the same treatment ranged from 1 to 15 miles.

Spray Applications

Sprays were applied either during the mornings (0600-0900 hrs) or evenings (1800-2030 hrs) of the period May 11-20. To minimize spray mixing and tank contamination problems, as well as the number of adjustments to the spray boom, applications were scheduled as follows:

(1) 2 gal rate, water only;

(2) 4 gal rate, water only;

(3) 2 gal rate, water with adjuvants;

(4) 2 and 4 gal rates, oil.

The geographical distribution of spray blocks (treatment replicates), the limited size of the field crew, and the occurrence of satisfactory meteorological conditions (Table I) were major factors limiting the number of applications to four or fewer during a single day.

Effective swath width for the aircraft was judged to be 50 ft. From two to three flagmen (title page) stationed along premeasured transects at right angles to the swath direction, were employed to guide the aircraft from one edge of the spray block to the other. After each pass of the aircraft the flagmen moved 50 ft to the next swath guidance stations, thereby ensuring equidistant swaths and uniform spray coverage. When applicable, swaths progressed from a downwind to an upwind direction. Also, one or two extra swaths were at times applied along the upwind edge of the block to compensate for drift, and to the swath ends as "header" applications (Figure 8).

Spray Deposit Analysis

Kromekote cards (2.5 X 4 inches in size) were placed on the ground in stand openings or along roadways and fireguards at right-angles to the swath direction for the collection of spray deposits. Droplets were counted and measured using a microcard reader for estimates of:

(1) density (no/cm^2);

(2) drop diameter size range (μ);

(3) spray volume deposits.

In one block (comp. 145-146 B), 18-inch long cards were wrapped around wooden dowels (1-inch diameter, 10 ft long) placed vertically in stand openings. Deposits on these cards were used for visual examinations of simulated coverage of aerial sprays to the leaders of target trees.

Treatment Assessments

From a minimum of 788 to more than 3900 trees were examined in the treatment plantations during the period August 14-22 for evaluation of spray results. Sampling was restricted primarily to interior portions of each plantation, with bias towards trees occurring near stand openings. The numbers of weeviled leaders during 1971 (pre-treatment) were compared with corresponding numbers during 1972 (post-treatment) for the derivation of percent population change between years in each treatment. A natural population decline was noted and confirmed[1]; accordingly, Abbott's formula (1925) was utilized to compensate for this trend and to correctly interpret mortality due to spray treatment.

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1 R. Bowser, G.L.F.R.C., Angus, Ontario (personal communication)

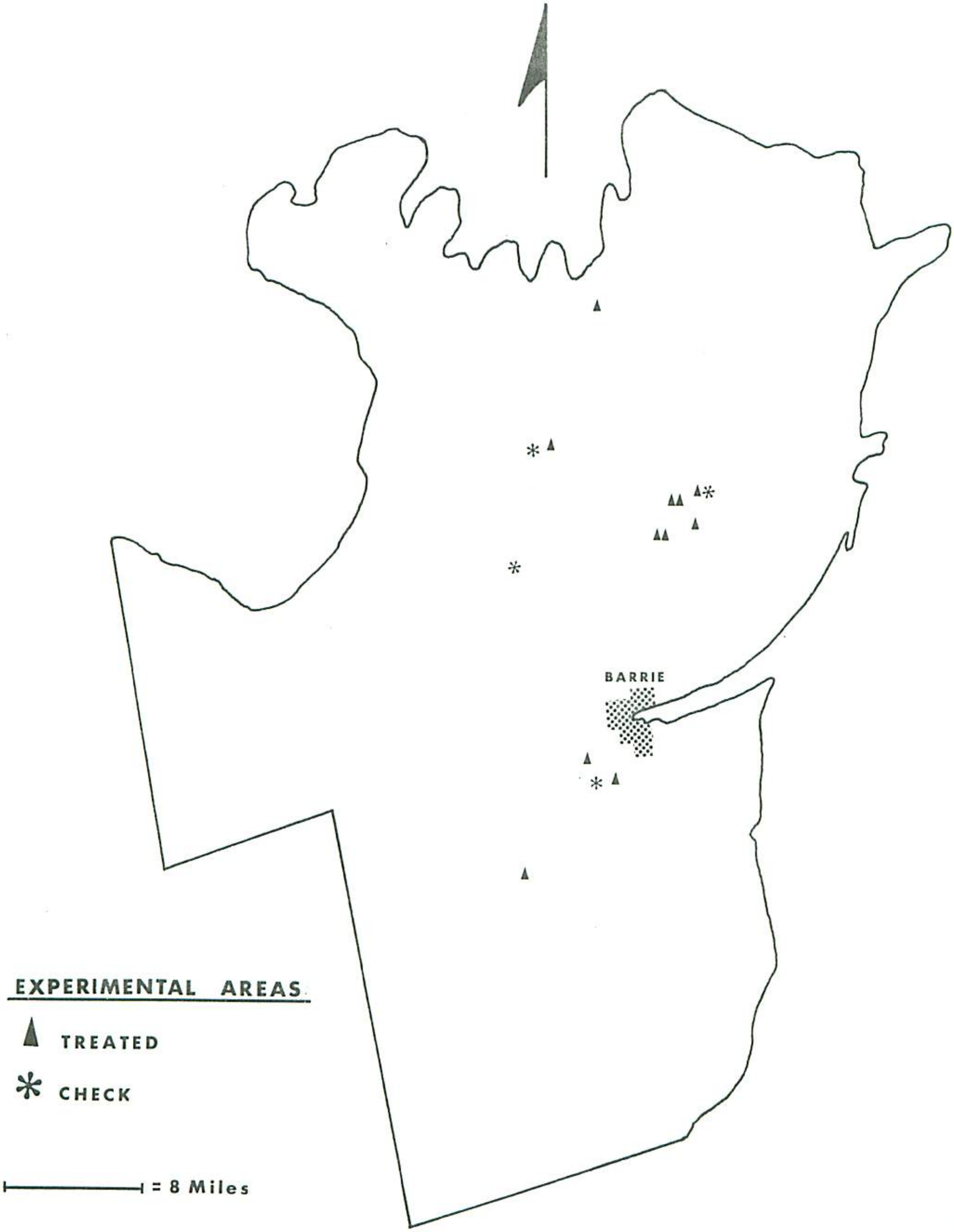

Figure 1. Location of methoxychlor spray treatment areas and untreated check plantations in Simcoe County, Ontario.

Figure 2. The Pawnee applying methoxychlor to an experimental spray area.

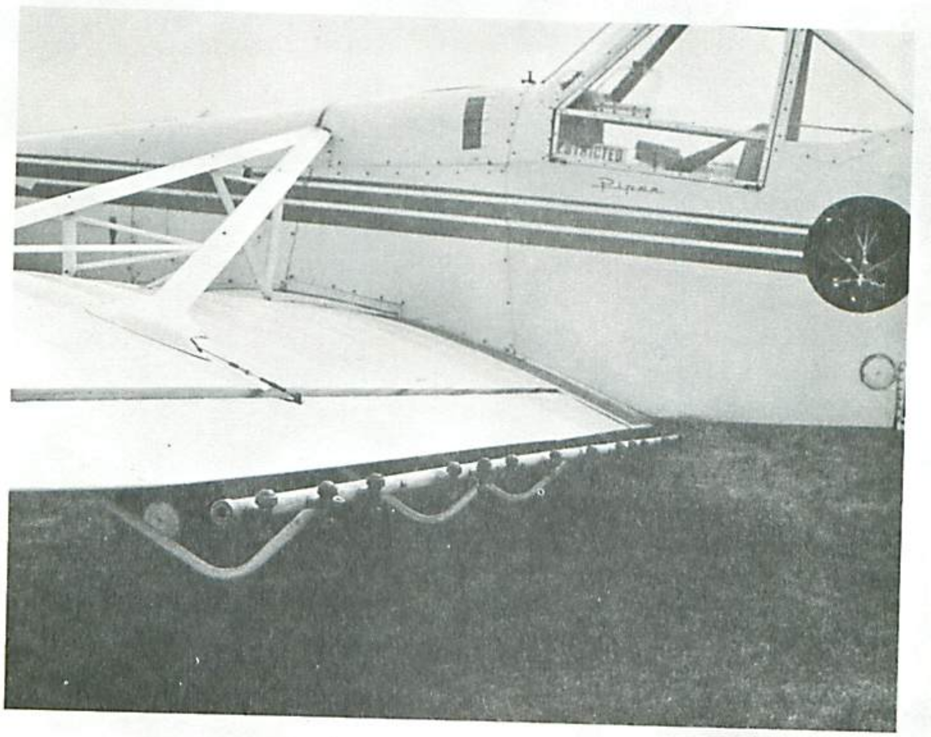

Figure 3. The aircraft spray boom fitted with Spraying Systems nozzles.

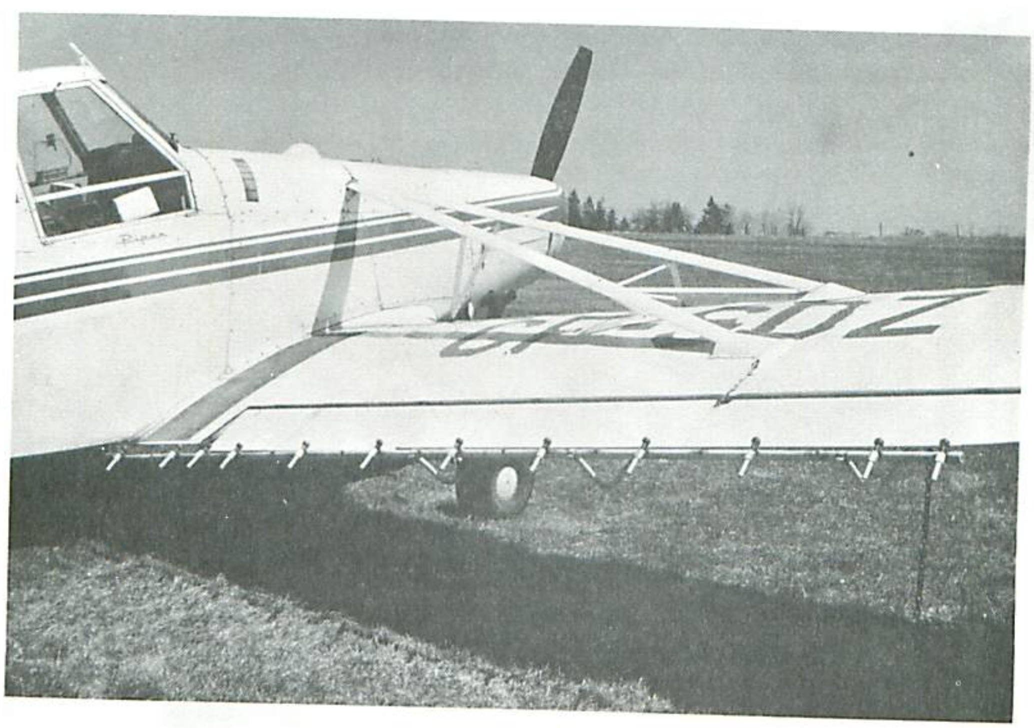

Figure 4. Delavan nozzles fitted to spray boom during calibration trials.

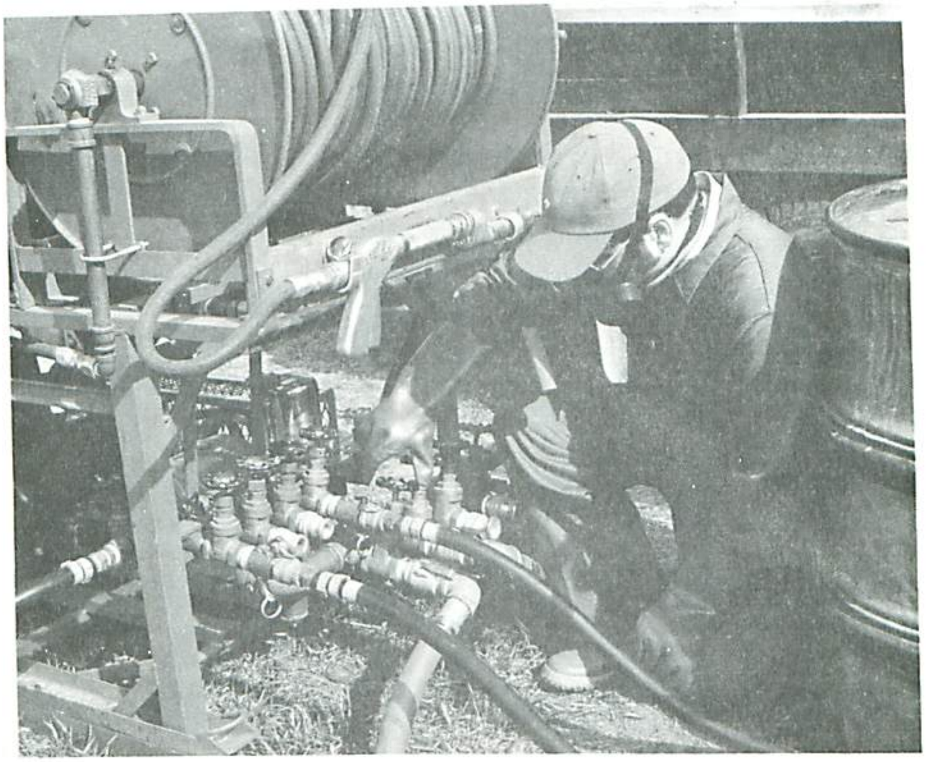

Figure 5. The CCRI experimental hydraulic sprayer used for loading the aircraft.

Figure 6. The Lutz transfer pump (R) and "Lightnin" mixer (L) used for spray preparations.

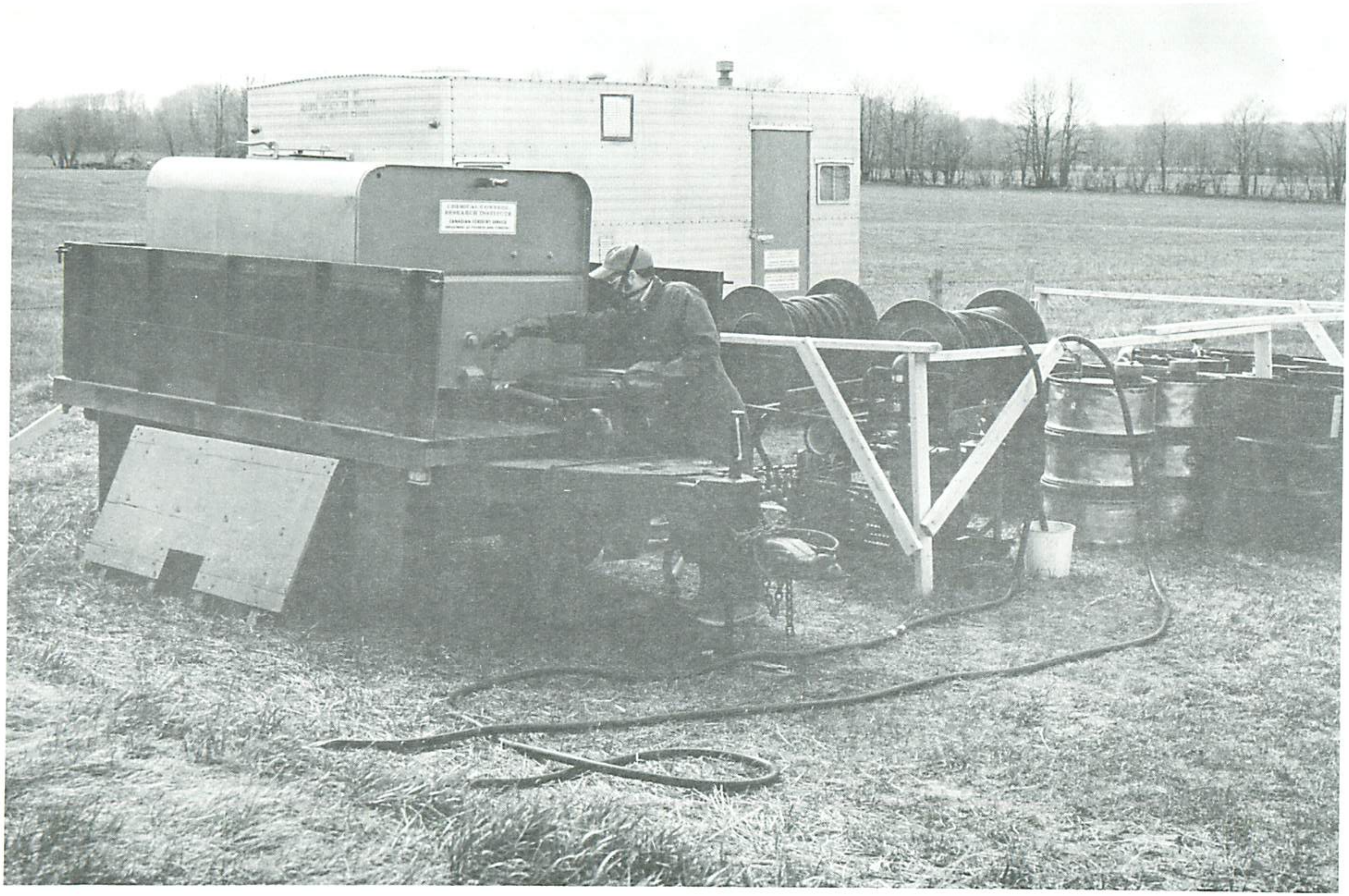

Figure 7. The storage compound and laboratory trailer at the Barrie Airport.

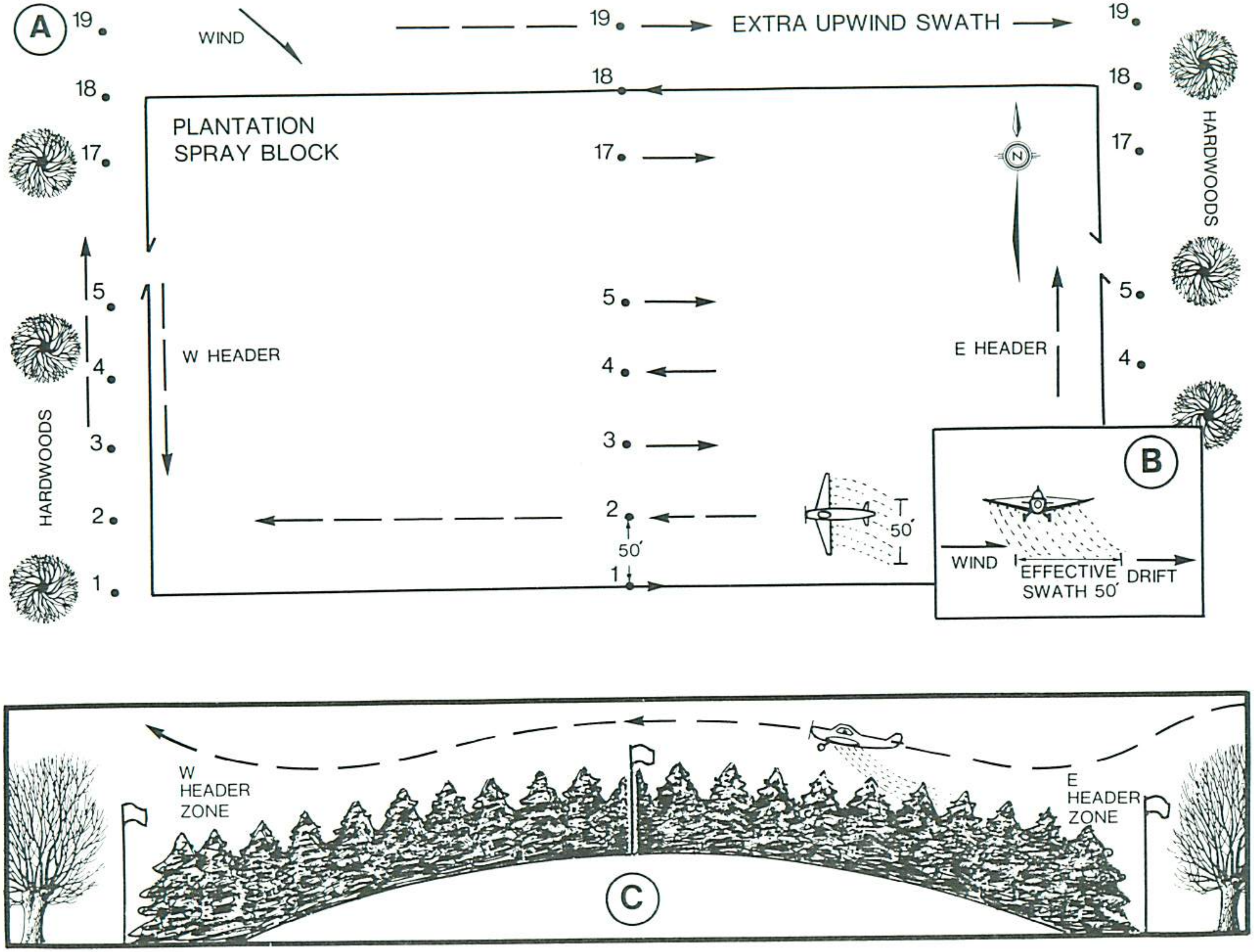

FIGURE 8 (A) Top view of a hypothetical aerial application showing swath lines (- -►) and locations of flag stations (•); (B) effect of light wind on swath width; (C) cross-sectional view of the plantation showing position of flags in relation to topography and obstacles (tall hardwoods) for swath-line sighting.

TABLE I. Methoxychlor spray treatments, plantation descriptions, and meteorological conditions during aerial applications in Simcoe Co., 1972

Treatment[1] (2.5 lb a.i./ acre .....)		Plantation				Meteorological Conditions				
		Replicate (OMNR Compart. No)	Height (Ft)	Age (Yrs)	Size (ac)	Spray Date (May)	Wind (mph)	Temp. (^oF)	R.H. (%)	Sky
I	4 gal oil	116	20	22	30	20 (am)	0-2	65	78	Clear
II	2 gal water/ Target E	140-141 A	16	19	25	13 (am)	2-5	54	48	Clear
		145-146 A	15	17	20	13 (am)	0-2	43	48	Clear
III	4 gal water	115	20	22	20	13 (am)	2-10	66	36	Clear
		140-141 C	16	19	20	15 (pm)	2-3	67	58	Overcast
IV	2 gal water 2x (immediately)	145-146 B	15	17	30	17 (pm)	2-5	71	56	Clear
V	2 gal water 2x (6-day interval)	230-231	15	15	30	12 (am)	2-6	53	63	Clear
						18 (am)	2-5	65	68	Clear
		233	15	15	23	12 (pm)	2-5	55	60	Clear
						18 (am)	2-4	57	72	Clear
VI	2 gal oil	45	15	18	23	19 (pm)	0-2	72	75	Clear
		111	20	22	20	20 (am)	0-2	48	92	Clear
VII	2 gal water/ Pinolene	140-141 B	15	18	38	18 (pm)	2-4	68	80	Clear
		143 A	20	24	25	18 (pm)	2-5	78	60	Clear
VIII	2 gal water/ Fomark	143 B	24	24	23	19 (am)	2-8	54	65	Clear
		145-146 C	15	17	26	19 (am)	2-8	62	69	Clear
IX	2 gal water	73	14	17	28	11 (am)	2-8	44	47	Scat. Cloud
		248	18	20	25	12 (am)	0-2	36	46	Clear
X	Untreated Check	76	12	15	10	---	---	--	--	---
		111	20	22	50	---	---	--	--	---
		166	15	18	52	---	---	--	--	---
		235	10	12	64	---	---	--	--	---

[1] Ranked according to efficacy per Table III; for treatments IV and V, methoxychlor @ 1.25 lb a.i./2 gal/ac each application.

TABLE II. Methoxychlor spray formulations (Imperial liquid measure)

WATER-BASE SPRAYS (ingredients/100 gal)			OIL-BASE SPRAYS (ingredients/100 gal)		
			1. SPRAYS at 2 gal/acre		
Methoxychlor 25 EC	-	50 gal	Methoxychlor technical grade	-	125.0 lb
Water	-	50 gal	Xylene	-	37.5 gal
Dye (Rhodamine B liquid)	-	16 fl oz	No. 2 fuel oil	-	50.0 gal
Adjuvants[1]	-		Dye (DuPont Oil Red Powder)	-	0.5 lb
			2. SPRAYS at 4 gal/acre		
Methoxychlor 25 EC	-	25 gal	Methoxychlor technical grade	-	62.5 lb
Water	-	75 gal	Xylene	-	18.75 gal
Dye (Rhodamine B liquid)	-	16 fl oz	No. 2 fuel oil	-	75.0 gal
			Dye (DuPont Oil Red Powder)	-	0.5 lb

[1] Adjuvants (when used) - Fomark (C.D. 587) @ 0.9 fl oz/gal spray, or,
NU-Film-17® (Pinolene) @ 2.0 fl oz/gal spray, or,
Target E® @ 8.0 fl oz/gal spray.

RESULTS AND DISCUSSION

Efficacy of Treatments

Only one of the nine spray treatments was effective in reducing weevil population density to a level whereby the incidence of subsequent leader injury was considered acceptable. This was the application of 2.5 lb methoxychlor in 4 gal oil/acre (Treatment I, Table III) where the percentage of weeviling after treatment was less than 1% and the reduction in leader attack from 1971 to 1972 was 87%. Seven other treatments (II-VIII) reduced the incidence of weeviling during 1972 to 7.6% or less, but when expressed on the basis of change between years, the reduction in leader injury ranged from only 59% to 75%. The treatment used operationally in Ontario during the period 1969-1971 (Treatment IX) reduced weevil attack by less than 50% and was the least effective of all.

Oil-based sprays were approximately four times as effective as aqueous spray solutions in reducing weevil densities (I vs III, VI vs IX), while applications of 4 gal spray mixture/acre were superior to sprays at 2 gal/acre (i.e., I vs VI, III vs IX). Differentials in protection levels achieved with water-base sprays (sans adjuvant) at 4 gal/acre were inconsequential whether applied as a single spray, as two applications of 2 gal/acre immediately, or as two applications of 2 gal/acre at a six-day interval.

Each of the three adjuvants enhanced spray efficacy at the 2 gal rate (Treatments II, VII, and VIII vs IX). Of these, Target E appeared to be the most effective additive. Differences between the methoxychlor plus Target E treatment and those with Pinolene and Fomark could have been due to the lower concentrations used of either of the latter two adjuvants, differences in the physical characteristics and break-up of the spray droplets, and/or the impact of certain meteorological conditions (e.g., wind, RH, temperature) on spray deposition during the applications.

Spray Deposits

Droplet size is one of the key factors in the resultant toxicological efficacy of aerial applications of insecticides. Himel (1969) has stated: "The optimum size for insecticide spray droplets is that size which gives maximum control of the target insect with minimum insecticide and minimum ecosystem contamination. Spray droplets found to be efficient in delivery of insecticide to the target insect are those with size range allowing them to be airborne and to be transported to the target by atmospheric transport and diffusion. Therefore, optimum-size droplets are those sizes small enough to be produced in maximum numbers for maximum coverage and large enough to have an optimum critical impingement velocity for optimum impingement on the target insect." His data suggest that optimum spray droplet diameter size may be in the vicinity of 20 μ for control of certain agricultural and forest insects. Unfortunately, the critical droplet size for effective control (e.g., for contact with feeding adults or for contact with bark surfaces) of the white pine weevil is unknown. Potts (1958), however, has indicated that small droplets are most effective and that 1000+ droplets/in^2 (= 155/cm^2) of bark surface are required to effect good control of the weevil.

Spray formulation (e.g., water- or oil-base mixtures) may also be critical in reference to spray coverage and spray efficacy. Howitt (1972) has shown that a water droplet 50 µ in diameter ($60^{\circ}F$, 40% RH) has a "lifespan" of 4 seconds, a droplet 100 µ in diameter 16 seconds, and a 200 µ droplet about 63 seconds. Similarly, in studies of droplet decay of oil solutions of insecticides, Hopewell (1959) has shown that volume decreases vary according to the volatility of the chemical components of the drops. With relatively volatile oil solutions (domestic fuel oil), for example, droplets of 50 µ diameter could shrink rapidly so that their rate of fall would decrease appreciably and they would then become more prone to drift from the target. Less volatile oil droplets of the same diameter, on the other hand, could be deposited at a greater rate of fall and thus would be more likely to reach the target.

The results (Table IV) of the spray droplet deposit analysis indicated that more methoxychlor reached the target area (the leader) when applied in oil solutions. Deposits of aqueous solutions were, on the average, only about one-third the amounts of the oil-based sprays (at equivalent rates of emission) due to the factors mentioned above. The reader is cautioned, however, to note that deposit analyses may be subject to appreciable error. It should be mentioned again that the flying height of the aircraft above treetops was generally in the range of 5 to 20 feet. The placement of deposit cards on the ground in stand openings and along roadways, then, is one obvious source of error masking the true picture of spray deposits on tree tops 10-25 feet above ground level. The distance between spray boom and deposit card thus could have varied from 15 to 45 feet, and these vertical fluctuations could have accounted for non-recovery on sample cards of many fine droplets 50 μ in diameter or smaller. Accordingly, these droplets may or may not have reached tree tops, regardless of the droplet volatility factor, but most probably did not reach the deposit cards below.

On several occasions visible spray droplet stains were timed for the interval between droplet emission and impingement. Generally, all visible droplet stains appeared within 25-30 seconds after the overpass of the aircraft some 25-40 feet above. Although individual spray treatments were subject to varying rates of evaporation, it was possible that most spray emission-to-target losses were due to the variable wind velocities and air turbulence which resulted in drift of the spray clouds and loss of fine droplets. Not more than 70% of the spray volume emitted during any single application reached ground level, while the average deposit for all water-base sprays was only about 20% of the emitted rates (Table IV).

Mean volume diameters of droplets for all aqueous spray solutions was about 150 μ, whereas the mean droplet size range for oil-based sprays was about 175-220 μ. Coverage in terms of droplet numbers/ cm^2 varied from fewer than 10 coarse drops to more than 100 usually ranging in size from 40 to 600 μ. Deposits, as expected, were inversely proportional to wind speed. Thus, with few exceptions not more than 100 relatively large droplets/cm^2 (vs Potts' (1958) requirement of 155 small droplets/cm^2) were deposited on the cards at ground level.

Examinations of droplet deposits on cards wrapped around wooden dowels placed vertically at leader heights indicated that about 90% of the spray droplets reaching the leaders was deposited on the upwind side. Volume deposits to the downwind card surfaces after a second application increased by only about 1% even after a 90^{o} change in swath pattern (and no change in wind direction). With unavoidable impingement on foliage of the leader as an important barrier to deposition on bark surfaces, probably less than 10% of this amount in turn would reach the bark and any exposed weevils on the upwind side while only a few drops, if any, would penetrate through downwind. Aerial applications, therefore, may be effective against only a small proportion of the weevil population on the leaders, and, in fact, their highest impact may be on those individuals in the ground litter and on other exposed resting locations. In summary, then, spray volume loss due to drift and evaporation, droplet impingement on leader foliage, uneven spray coverage to the leader, and the application of a possible inefficient mean droplet diameter spectrum (150-220 μ) may be listed among the reasons for the unsatisfactory protection levels achieved with most of the methoxychlor spray treatments by aerial application.

The results summarized in Table IV have indicated for these experimental conditions, however, that greater insecticide deposition will reach target leaders if spray mixtures are formulated as oil solutions. Also, the higher the spray volume rate of application, the more satisfactory was the level of protection (Table III).

The addition of one adjuvant, Target E, to emulsions of methoxychlor also indicated an interesting alternative to increase in volume and/or change to oil spray formulations. It was evident (Table IV) that the addition of this adjuvant greatly increased spray deposition on target, and that spray volume may be kept at a relatively low rate (e.g., 2 gal spray mixture/ac) providing the optimal droplet size is applied. It would appear, therefore, from this preliminary and incomplete analysis of spray deposition that either oil or water/adjuvant sprays from the air may successfully reduce weevil injury to acceptable levels only if uniform and small droplets in the range of 20-70 μ and at densities of 100+/cm^2 reach the bark surfaces of leaders. This requirement possibly can be met with more sophisticated emission equipment such as the Micronair AU 3000 atomizers or the Becomist scintered sleeve spray units.

Application Technique

Nigam (1972) has shown that methoxychlor has only about one-tenth the toxicological potency of lindane against white pine weevil adults. The recent work by Sundaram et al (1972), however, has indicated the chemical half-life of methoxychlor to be about 26 days on white pine leaders, a period long enough to span the greater portion of the adult activity period in May. This information, then, in addition to the knowledge that ground spray applications of this insecticide provide excellent protection of leaders (DeBoo and Campbell 1971, 1972), supports the following general conclusion: Methoxychlor treatments applied by aircraft to white pines during May are effective in preventing weevil injury only if adequate coverage to the leaders is obtained at the commencement of the feeding/oviposition period. The timing of sprays and deposit coverage on the leaders should be considered as the major criteria limiting spray efficacy.

The results of the current research program suggest that the priority for continued investigation of aerial spray efficacy of methoxychlor be centered on improvement of application technique. Although not as effective as lindane, the insecticide most commonly used for weevil control outside Ontario, methoxychlor as a spray treatment meets most of the provincial requirements for environmental protection as well as for insect control. Before turning to alternative chemicals, therefore, it is recommended that additional evaluations of aerial spray methods using this insecticide be conducted for control of the weevil during 1973.

TABLE III. Results of aerial applications of methoxychlor for control of white pine weevil in Simcoe Co., 1972

Treatment[1] (2.5 lb a.i./acre in ..)		Leader injury by white pine weevil				Percent Reduction in Leader Injury[2] (Between Years)
		1971		1972		
		No weeviled/ No examined	Percent weeviled	No weeviled/ No examined	Percent weeviled	
I	4 gal oil	77/788	9.8	5/827	0.6	87
II	2 gal water/Target E	353/1612	21.9	68/1595	4.3	75
III	4 gal water	151/1439	10.5	38/1437	2.6	70
IV	4 gal water (2x 2 gal immediately)	388/1478	26.3	70/917	7.6	66
V	4 gal water (2x 2 gal @ 6-day interval)	442/2356	18.8	145/2582	5.6	65
VI	2 gal oil	215/2048	10.5	73/1795	4.1	61
VII	2 gal water/Pinolene	204/1424	14.3	70/1403	5.0	60
VIII	2 gal water/Fomark	266/1521	17.5	87/1385	6.3	59
IX	2 gal water	542/2010	27.0	298/1991	15.0	41
X	Untreated check	656/3805	17,2	630/3928	16.0	7

[1] Ranked according to efficacy; all treatments single applications unless specified otherwise.

[2] Corrected by Abbott's formula.

TABLE IV. Spray droplet size, density and volume deposits

Treatment[1]		Droplet[2]				Deposit[3]	
Methoxychlor @ 2.5 lb a.i./ac in ...		Mean volume diameter (μ)	Av. size -diameter class range (μ)	Maximum diameter (μ)	Av. No /cm²	% of vol. emitted collected on cards	Approximate volume in oz/ac collected on cards
I	4 gal oil	219	87-745	874	n.a.	n.a.	n.a.
II	2 gal water/Target E	147	55-490	553	73	52	166
III	4 gal water	147	55-495	602	57	19	122
IV	4 gal water (2x 2 gal/ac immediately)	141	55-432	432	62	21	134
V	4 gal water (2x 2 gal/ac @ 6-day interval)	142	55-464	464	45	18	115
VI	2 gal oil	176	87-678	719	54	68	218
VII	2 gal water/Pinolene	130	55-449	449	36	18	58
VIII	2 gal water/Fomark	n.a.	n.a.	n.a.	12	n.a.	n.a.
IX	2 gal water	140	55-385	449	26	17	54

[1] Ranked according to efficacy per Table III.

[2] Not necessarily indicative of droplets at leader heights.

[3] Approximate, and subject to considerable error.

SUMMARY AND CONCLUSIONS

In summation, the results of preliminary experimental applications of methoxychlor by aircraft at 2.5 lb a.i./ac have indicated that:

1. Control of white pine weevil adults is difficult to achieve, and is less effective than high-volume applications of equivalent dosages of the insecticide by hydraulic sprayer.
2. Better control (but unsatisfactory from the stand protection viewpoint) was achieved with 4 gal of spray formulation per acre than at 2 gal/acre.
3. Oil spray applications were more effective under the described experimental conditions than applications of water-based sprays at equivalent rates of emission.
4. One adjuvant, Target E, when added to aqueous solutions and then applied as 2 gal spray mixture/acre, apparently increased insecticide deposits by about 50%. The protection level achieved by this treatment was exceeded only by the protection achieved with the highest volume oil spray.
5. The major problem in control of the white pine weevil using spray aircraft appears to be one of obtaining adequate coverage of the leader. Aerial applications by fixed-wing aircraft are subject to displacement by air currents; accordingly uniform distribution of small droplets to all bark surface area on leaders is difficult, if not impossible, to achieve.
6. Investigations of aerial applications of methoxychlor should be continued during 1973 with improvement of spray deposition on leaders as a major objective.

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