TOPICAL APPLICATIONS OF CHLORPYRIFOS AND VARIOUS OIL DILUENTS AGAINST MOUNTAIN PINE BEETLE AND SPRUCE BEETLE IN THE PRINCE GEORGE FOREST REGION

by

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ABSTRACT

Topical applications of the organophoshate insecticide chlorpyrifos and various oil diluents were used against spruce beetle, Dendroctonus rufipennis (Kirby) and mountain pine beetle, D. ponderosae Hopkins. Treatments were applied to the bark of felled infested lodgepole pine, Pinus contorta Doug. var latifolia Engelm., or felled interior spruce, Picea glauca x engelmannii, either before adult emergence (spring/summer) or after host attack (October). Diesel oil was just as effective as the chlorpyrifos (5% a.i.) formulations against spruce beetle and mountain pine beetle progeny. AWK oil (a low aromatic content mineral oil) was just as effective as the chlorpyrifos (5% a.i.) formulation against mountain pine beetle when applied either 2 months prior to adult emergence or 3 months after host infestation. The application of insecticides against Dendroctonus spp. beetles is a promising strategy to supplement other more traditional methods of beetle management in B.C.

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TOPICAL APPLICATIONS OF CHLORPYRIFOS AND OIL DILUENTS AGAINST MOUNTAIN PINE BEETLE AND SPRUCE BEETLE IN THE PRINCE GEORGE FOREST REGION

I. INTRODUCTION

The two most serious bark beetle pests of forests in British Columbia are the mountain pine beetle, Dendroctonus ponderosae Hopkins, and the spruce beetle, D. rufipennis Kirby (Furniss and Carolin 1977). In 1987, mountain pine beetle (MPB) infested 64,470 ha of lodgepole pine, Pinus contorta var. latifolia, and spruce beetle infested 3,000 ha of interior spruce, Picea glauca x P. engelmannii (Wood et al. 1988). Both beetles have killed thousands of hectares of timber in various regions of B.C. and they continue to have major impacts on forest management activities.

Customary bark beetle management approaches have included those listed in Table 1. There are occasions when the use of these more traditional single tree treatments are limited or restricted because of: (1) the relative labour-intensive high costs of piling and burning; (2) the fire hazard restrictions of burning infested stems between April and November; and, (3) the critical timing required when using MSMA.

There are instances when the use of a topically-applied insecticide would alleviate some or all of the above constraints. Various insecticides have been tested against Dendroctonus spp. beetles since the 1930's in an attempt to find the best formulations and methods of application. These insecticides have included: naphthaline (Salman 1938); dichlorobenzene, ethylene dibromide (EDB), dichloroethyl ether, fuel oil, DDT, and

Table 1. Common practices to manage mountain pine beetle and spruce beetle in British Columbia.

Management practice	Mountain pine beetle	Spruce beetle
Sanitation logging of infested stands	X	X
Felling and burning	X	
Post-attack injection of MSMA[a]	X	
Pre-attack injection of MSMA		X[b]
Conventional (untreated) trap trees		X
Use of semiochemicals[c] in conjunction with above practices	X	X

[a] monosodium methane arsenate

[b] includes felling of tree two weeks after injection

[c] commonly a pheromone which attracts members of the same species

benzene hexachloride (BHC) (Schmid 1972, Schmid and Frye 1977); orthodichlorobenzene (Klein 1978); and lindane (Tilden 1985). Although lindane has federal registrations for MPB suppression (Henigman and Beardsley 1985), it is not used in B.C. forestry because of its environmental persistence.

In an attempt to find an efficaceous alternative to lindane, McMullen[1] sprayed chlorpyrifos (2% a.i.) in diesel oil on MPB-infested lodgepole pine (Pl) bolts in early July and killed 98.7% of new adults. The treatment was more effective than lindane (1% a.i.) in diesel oil. Werner et al. (1983) tested aqueous formulations of chlorpyrifos against spruce beetle adults in spruce bolts in the spring. Chlorpyrifos at 2% killed 98% of emerging spruce beetles up to 12 weeks after treatment.

Tilden (1985) applied chlorpyrifos and other insecticides against newly mature MPB adults in Pl bolts. He observed that a formulation of 2% chlorpyrifos in water was just as effective as a formulation of 0.6% lindane in water in reducing emergence of MPB. Fuchs and Borden (1985) demonstrated that aqueous formulations of 2% chlorpyrifos and 2% carbaryl killed 94.9% and 85.8% of MPB adults, respectively, when applied to Pl bolts 11 days prior to the start of adult emergence. Based on the latter research, aqueous formulations of

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[1] Unpublished report (1980), Pacific Forestry Centre, Canadian Forestry Service, Victoria, B.C.

2% chlorpyrifos and 2% carbaryl are now registered for suppression of MPB prior to adult emergence in the spring.

There are, however, operational requirements to also treat infested trees earlier in the spring as soon as they are discovered (e.g., April to June) when fire hazard conditions negate piling and burning. Spray applications may also be feasible and cost-efficient against young MPB and spruce beetle larvae in newly infested hosts in September and October. Applications at such times may require a higher dosage of chlorpyrifos and/or a more penetrating or persistent diluent to be effective on colder phloem tissues.

The objectives of this report are threefold:

1) review the efficacy of chlorpyrifos and various oil diluents used against spruce beetle and MPB in trials conducted in the Prince George Forest Region between 1982 and 1986;

2) based on current information, make recommendations for the operational use of recently registered insecticides against MPB and spruce beetle in B.C.;

3) identify gaps in existing knowledge of the operational use of insecticides against Dendroctonus spp. beetles.

II. METHODS

A. Spruce Beetle Trial No. 1

In the Prince George East Forest District in 1981, a total of 55 spruce trap trees at 11 remote locations required treatment to kill developing spruce beetle larvae (Hodgkinson 1983). Four of 5 trap trees at each site were delimbed and the lopped branches were pulled away from the trap trees and stumps to allow walking access along each side of the bole for the insecticide applicator (Fig. 1). One of the 5 trap trees at each site was left untreated to serve as a check for assessing chlorpyrifos efficacy.

In late October and early November 1981, chlorpyrifos at 2.4% (a.i.) in diesel oil was sprayed from a backpack sprayer (with a fan nozzlehead) to the drip-point on trap trees. Insecticide coverage of the beetle-infested portion of the boles was almost total, and it was not deemed cost-efficient to buck and roll sections of the trap trees in order to achieve small additional coverage. Trees were left over the winter and sampled for treatment efficacy on June 9-11, 1982 - 7.5 months after treatment. Four 400 cm^2 bark samples were removed from each trap tree on opposite, lower lateral surfaces; sample pairs being removed at 4 m and 20 m from the butt.

Figure 1. Application of chlorpyrifos (2.4% a.i.) in diesel oil on spruce beetle infested trap tree.

Note that the bole has been delimbed to facilitate applicator access along both sides of the felled tree. (Prince George East Forest District - October 1981).

2. Spruce Beetle Trial No. 2

On July 12, 1982, eighteen 1.5 m bolts were sawn from freshly-attacked felled spruce trap trees in the Prince George East Forest District (Marshall[2]). Since the top sunnier surfaces of trap trees are less attacked than shaded undersides, a spot on the top of each bolt was marked with spray paint so bolts could be re-positioned later in their original orientation.

The bolts were transported to a partially wooded area in the Forest Service Compound in the City of Prince George and the ends of each bolt were sealed with paraffin. Bolts were then randomly arranged in 3 groups of 6 bolts each under separate branch-covered wooden canopies which simulated forest shading. Bolts were placed parallel to the ground to simulate felled trees and spaced approximately 20 cm apart (Fig. 2).

On July 16, 1982, each of the 3 groups were treated with one of the following: (1) chlorpyrifos at 2.4% (a.i.) in diesel oil; (2) diesel oil alone; or, (3) left untreated to serve as checks. Bolts were sprayed to the drip-point with their respective treatments. Efficacy sampling was conducted on August 23-24, 1982 - 5 weeks after treatment. Two 400 cm^2 bark samples were removed from opposite sides of each bolt from the lower lateral surfaces.

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[2] Unpublished report (1982), Prince George Forest Region, B.C. Ministry of Forests and Lands, Prince George, B.C.

Figure 2. Arrangement of a group spruce bolts under a shading canopy.

Note: This particular group is being treated with diesel oil

B. RESULTS

1. Spruce Beetle Trial No. 1

The total volume of the chlorpyrifos formulation (2.4% a.i.) in diesel oil required to treat 1 trap tree and stump to the drip-point was approximately 23-30 litres (L). Treatment time per trap tree, including re-filling time, was approximately 30 minutes per applicator.

During the intervening winter between treatment and efficacy sampling, a maximum of approximately 2 m of snow covered these treated trees. Chlorpyrifos killed 63% of larvae and callow adults (Table 2)(Fig. 3), and natural mortality of the overwintering larvae and callow adults was 26%. McCambridge and Knight (1972) recorded a 17% natural mortality rate of spruce beetle brood overwintering in snow-covered trap trees. If natural mortality had been lower in this trial (as in spruce beetle trial no. 2), the chlorpyrifos formulation would probably have shown a higher percent toxicity against the various surviving life stages.

2. Spruce Beetle Trial No. 2

During the 5-week interval between treatment and efficacy sampling, the summer weather was average for the area with no heavy rains. The treatments killed 79-82% of larvae and callow adults (Table 3). There were no significant differences between the efficacy of the chlorpyrifos formulation and the diesel oil alone treatment. Percent natural mortality of the overwintering larvae was 19% - somewhat less

Table 2. Efficacy of chlorpyrifos[a] against spruce beetle larvae and callow adults in trap trees.

Treatment	Mean no. of larvae and callow adults[b] living	dead	total	Percent mortality* from treatment
Chlorpyrifos + diesel oil	1.7 ± 4.5[c]	14.3 ± 18.5[c]	16.0[c]	63%
Check	13.5 ± 18.8[d]	4.8 ± 11.0[d]	18.3[c]	--

[a] Dursban-4E® formulated at 2.4% (a.i.) in diesel oil

[b] Based on the $\bar{x}$ data from 36 (400 cm^2) bark samples; 4 samples from each of 9 trap trees

[c] Means within a column followed by different letters are significantly different at $p < 0.01$ (± standard deviations) (Mann-Whitney non-parametric test, Snedecor and Cochran 1972)

* Adjusted by Abbott's Formula for natural mortality (Abbott 1925)

Figure 3. Spruce beetle larvae killed by an application of chlorpyrifos (2.4% a.i.) in diesel oil in October 1981.

Note: This slide was taken during efficacy sampling in early June 1982 - 8 months after treatment. The putrified larvae were probably killed prior to the onset of winter, and thus had time to partially decompose before the arrival of colder temperatures.

Table 3. Efficacy of diesel oil alone and in combination with chlorpyrifos[a] against spruce beetle larvae and pupae in spruce bolts.

Treatment	Mean no. larvae and callow adults[b] living	dead	total	Percent mortality* from treatment
Diesel oil	0.8 ± 2.3[c]	26.0 ± 15.6[c]	26.8[c]	79%
Chlorpyrifos + diesel oil	0[c]	30.8 ± 12.2[c]	30.8[c]	82%
Check	16.7 ± 17.4[d]	3.8 ± 3.8[d]	20.5[c]	--

[a] Dursban-4E® formulated at 2.4% (a.i.) in diesel oil

[b] Based on the $\bar{x}$ data from 36 (400 cm^2) bark samples; 4 samples from each of 6 replications

[c] Means within a column followed by different letters are significantly different at $p < 0.05$ (± standard deviations) (Mann-Whitney non-parametric test, Snedecor and Cochran 1972)

* Adjusted by Abbott's Formula for natural mortality (Abbott 1925)

than encountered in trial no. 1. The results suggest that diesel oil alone is effective in killing spruce beetle larvae and pupae in the phloem when applied in July of the year of attack.

III. MOUNTAIN PINE BEETLE TRIALS

A. METHODS

1. Mountain Pine Beetle Trial No. 1

On October 10, 1985, several MPB-infested lodgepole pine were felled and bucked into eighteen 1.5 m bolts in the Vanderhoof Forest District. These were transported to the same test area as in Sect. II A 2 ; the ends of each bolt were sealed with paraffin and bolts were positioned parallel to the ground in 3 random groups of 6 bolts each to simulate felled stems. On May 21, 1986, each of the 3 groups were randomly treated with one of the following : (1) chlorpyrifos at 5% (a.i.) in diesel oil; (2) diesel oil alone; or, (3) left untreated to serve as checks. Bolts were sprayed to the drip-point with their respective treatments. Efficacy sampling was conducted on June 16, 1986 - 26 days after treatment and approximately 1 month prior to expected adult emergence. Sampling was identical to that employed in Sect. II A 2.

2. Mountain Pine Beetle Trial No. 2

On October 9, 1986, a total of 15 P1 bolts currently infested with MPB larvae were transported from the Vanderhoof Forest District to the same test area as in the above trials. Bolts were sealed with paraffin and positioned in similar groups as in the above trials.

On October 15, 1986, each of the 3 groups of bolts were treated with one of the following: (1) chlorpyrifos at 5% (a.i.) in AWK[3] oil; (2) AWK oil alone; or, (3) left untreated to serve as checks. Bolts were sprayed to the drip-point with their respective treatments. Efficacy sampling was conducted on June 18-19, 1987 - 8 months after treatment and approximately 1 month prior to expected adult emergence. Four 400 cm^2 bark samples were removed from the lateral portions of each bolt.

B. RESULTS

1. Mountain Pine Beetle Trial No. 1

Table 4 shows the efficacy data and the percent mortalities per treatment. Mortality to MPB progeny was 71% from the diesel oil treatment and 88% from the chlorpyrifos formulation. Natural mortality of progeny was 12%. There was no significant difference between the efficacy of the 2 treatments. Both treatments were, therefore, efficaceous in killing MPB larvae, pupae and callow adults in P1 bolts in spring applications at least 2 months prior to expected adult emergence.

2. Mountain Pine Beetle Trial No. 2

During efficacy sampling there was considerable frass and boring debris present on phloem surfaces (Fig. 4), therefore, it was very

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[3] Agricultural Weed Killer - a low aromatic content mineral oil

Table 4. Efficacy of AWK oil[a] alone and in combination with chlorpyrifos[b] against mountain pine beetle larvae and pupae in lodgepole pine bolts.

Treatment	Mean no. larvae, pupae and callow adults[c] living	dead	total	Percent mortality* from treatment
Diesel oil	3.3 ± 4.8[d]	15.3 ± 8.2[d]	18.6[d]	71%
Chlorpyrifos + diesel oil	0[d]	21.8 ± 14.3[d]	21.8[d]	88%
Check	28.7 ± 23.4[e]	3.8 ± 3.4[e]	32.5[d]	--

[a] Agricultural Weed Killer (AWK) - a selective herbicidal mineral oil marketed by Shell Oil

[b] Dursban-4E® formulated at 5% (a.i.) in AWK oil

[c] Based on the $\bar{x}$ data from 10-12 (400 cm^2) bark samples; 2 samples from each of 5-6 lodgepole pine bolts

[d] Means within a column followed by different letters are significantly different at $p<0.05$ (± standard deviations) (Mann-Whitney non-parametric test, Snedecor and Cochran 1972)

* Adjusted by Abbott's Formula for natural mortality (Abbott 1925)

Figure 4. Phloem sample from a mountain pine beetle infested lodgepole pine bolt.

Note: This bolt was treated with AWK oil on October 15, 1986 and sampled for efficacy determination on June 18, 1987. Dead parent adults and dead larvae can be seen within incomplete egg galleries.

difficult to distinquish and tally small dead larvae. Consequently, only newly mature adults (living and dead) were used in the analysis. Table 5 depicts the mean number of new adults found after each treatment and their corresponding percent mortalities due to treatment. Both AWK oil alone and in combination with chlorpyrifos at 5% (a.i.) were effective in killing 93-95% of MPB in treated bolts. No significant differences occurred between the efficacy of the chlorpyrifos formulation and the AWK oil alone (Table 5). There was a 4.9% rate of natural mortality of those MPB that reached the new adult stage.

IV. SUMMARY AND RECOMMENDATIONS

A. Summary

Table 6 summarizes the efficacies of the various treatments applied against spruce beetle and MPB. From these trials it is apparent that:

1) spruce beetle progeny can be effectively killed in trap trees by topical applications of diesel oil alone or with 2.4 % chlorpyrifos when treated between mid-July and late October in the year of attack. Diesel oil is just as effective as the chlorpyrifos formulation.

2) MPB progeny can be effectively killed in felled Pl by topical applications of diesel oil alone or with chlorpyrifos (5%) when treated in the spring approximately 2 months prior to anticipated adult emergence.

Table 5. Efficacy of AWK oil[a] alone and in combination with chlorpyrifos[b] against mountain pine beetle in lodgepole pine bolts.

Treatment	Mean number of new adults[c] living	dead	total	Percent mortality* from treatment
AWK oil	0.6 ± 1.6[d]	0[d]	0.6[d]	92.6%
Chlorpyrifos + AWK oil	0[d]	0[d]	0[d]	95.1%
Check	23.2 ± 16.7[e]	1.2 ± 1.4[e]	24.4[e]	--

[a] Agricultural Weed Killer (AWK) - a selective herbicidal mineral oil marketed by Shell Oil

[b] Dursban-4E® formulated at 5% (a.i.) in AWK oil

[c] Based on the $\bar{x}$ data from 10 (400 cm^2) bark samples; 2 samples from each of 5 lodgepole pine bolts

[d] Means within a column followed by different letters are significantly different at $p < 0.05$ (± standard deviations) (Two-sample t-test, Snedecor and Cochran 1972)

* Adjusted by Abbott's Formula for natural mortality (Abbott 1925)

Table 6. Summary of efficacies of topical applications of chlorpyrifos and various oil diluents against mountain pine beetle and spruce beetle in the Prince George Forest Region

Dendroctonus beetle and trial number	Reference	Treatments	Host infestation date	Treatment date	Efficacy sampling date	Percent mortality of progeny from treatment
Spruce beetle trial no. 1	Hodgkinson (1983)	chlorpyrifos 2.4% (a.i.) in diesel oil	May/81	Oct./Nov./81	June 9-11/82	63%
Spruce beetle trial no. 2	Marshall (1982)[a]	chlorpyrifos 2.4% (a.i.) in diesel oil	May/June/82	July 16/82	Aug. 23-24/82	82%
		diesel oil	May/June/82	July 16/82	Aug. 23-24/82	79%
Mountain pine beetle trial no. 1	Hodgkinson (1986)[a]	chlorpyrifos 5% (a.i.) in diesel oil	July/85	May 21/86	June 16/86	88%
		diesel oil	July/85	May 21/86	June 16/86	71%
Mountain pine beetle trial no. 2	Hodgkinson (1987)[a]	chlorpyrifos 5% (a.i.) in AWK oil	July/86	Oct. 15/86	June 18-19/87	95%
		AWK oil	July/86	Oct. 15/86	June 18-19/87	93%

[a] unpublished reports or memoranda

3) MPB progeny were also effectively killed in felled Pl by topical applications of AWK oil alone or with chlorpyrifos (5%) when treated up to mid-October in the year of attack. AWK oil alone was just as effective as the chlorpyrifos (5%) formulation against MPB when applied either 2 months prior to adult emergence or 3 months after host infestation.

B. Recommendations

1) Based on previous field trials, aqueous formulations of 2% chlorpyrifos and 2% carbaryl (registered products) can, and should, now be used operationally against MPB in the late spring prior to expected adult emergence. Forest Regions should compile their own "Standard Operating Procedures" to detail specific use patterns based on their own local conditions. The following principles apply:

a) Application periods are from approximately mid-May to mid-June depending on local environmental conditions.

b) Infested Pl are felled and the branches are delimbed from the boles wherever pitchtubes are evident. This allows the applicator easy access to the boles for a more complete spray coverage.

c) Whenever possible, water from local streams or lakes should be used as a carrier for the insecticide formulation. This alleviates the necessity to transport water to the site. Care must be taken to ensure that the insecticide does not pollute the water source.

d) Infested stems should be sprayed to the drip-point by using a backpack sprayer with a fan nozzlehead or other suitable equipment. It may be necessary to buck and roll one or more sections of the boles to achieve sufficient insecticide coverage.

e) Treated boles should be inspected after the flight to determine insecticide effectiveness. A lack of adult exit holes and/or the presence of many dead new adults in the phloem tissue will normally indicate insecticide efficacy.

2) The cost of spraying insecticide formulations on felled trees should be compared to the cost of wintertime piling and burning. If insecticide treatment costs per tree are considerably cheaper, it may be more economically efficient in certain locations to dispose of Dendroctonus spp. before or after the winter. Like any treatment option, insecticide treatments should be carefully considered within an overall beetle suppression program.

3) Although water formulations of 2% chlorpyrifos and 2% carbaryl are registered for, and demonstrated effective against, MPB just prior to emergence, there have been no tests of their efficacy earlier in the spring or later in the fall. Treatments applied at such times may require a more persistent diluent with greater bark-penetrating properties in order to effectively kill various stages of MPB in colder phloem tissues. A test of the above insecticide formulations in the fall, and possibly early spring, is warranted.

4) A further trial should be undertaken with MPB in the fall to compare the efficacy of AWK oil alone against reduced dosages of chlorpyrifos (1-2% a.i.) in water. AWK oil should also be tested as a suitable replacement for diesel oil against spruce beetle. If the efficacy of AWK oil is as good or better than diesel oil and the various aqueous insecticide formulations, registration of AWK oil should be persued.

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