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Remedial Treatment of Lodgepole Pine Infested with Mountain Pine Beetle: efficacy of three insecticides

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The mountain pine beetle (*Dendroctonus ponderosae* Hopkins [Coleoptera: Scolytidae]) has caused significant mortality of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) in western North America,[1] resulting in ecological and management problems.[2] Remedial control of the mountain pine beetle has been done since the early 1900's.[3] A variety of toxic chemicals has been used since the 1930's, with water emulsions of ethylene dibromide[4] and lindane[5] being the most recent treatments.[6] The U.S. Environmental Protection Agency (EPA) has cancelled registration of ethylene dibromide as a felled log fumigant to control bark beetles.[7] Although the EPA has retained registration of lindane for bark beetle control,[8] forestry uses of lindane are controversial.[9] Therefore, alternatives to ethylene dibromide and lindane are needed.

This note describes a field study of three insecticides—chlorpyrifos, carbaryl, and fenitrothion—for remedial control of the mountain pine beetle, in the White River National Forest, Colorado. Infested bolts were sprayed with the insecticides at three different concentrations and with lindane at the registered dosage of 0.6 pct active ingredient. Numbers of beetles emerging from bolts were compared between treatments and untreated checks. Chlorpyrifos and fenitrothion at 2 and 4 pct active ingredient were about as effective as lindane in reducing emergence of mountain pine beetle from infested lodgepole pine bolts.

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Lindane is registered for remedial control of bark beetles; however, forestry uses are controversial and alternative chemicals are needed. Chlorpyrifos (Dursban 4E), carbaryl (Sevimol 4), and fenitrothion (Sumithion 8E) at 1, 2, and 4 pct active ingredient, and lindane at the registered dosage of 0.6 pct were sprayed on lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) bolts infested with mountain pine beetles (*Dendroctonus ponderosae* Hopkins) in Colorado. Mean survival ratios (n=10) of the proportions of beetles emerging from treated bolts to the proportion emerging from control bolts indicated that chlorpyrifos and fenitrothion at 2 and 4 pct were about as effective as lindane in reducing emergence.

Retrieval Terms: mountain pine beetle, *Dendroctonus ponderosae,* insecticide, remedial control, Dursban, Sevimol, Sumithion, chlorpyrifos, carbaryl, fenitrothion, White River National Forest, Colorado

MATERIALS AND METHODS

The study was done during summer 1983 on the Dillon Ranger District, near Dillon, Colorado. The initial experimental design was to randomly assign one bolt from each of 11 trees to each of 10 treatments, and two bolts from the 11 trees (for an estimate of within-tree variance) to an untreated check, for a total of 110 treated bolts and 22 bolts for the check. Of the 15 trees felled on June 28, however, only 10 were sufficiently infested to provide 11 or more 30-cm-long bolts, 15 to 25 cm in diameter. Developmental stages of the beetles, checked by chipping away small pieces of bark, were late larvae, pupae, and callow adults. One bolt from each of the 10 trees plus one additional bolt chosen from trees with more than 11 bolts, were randomly assigned to each treatment.

Insecticides were chosen on the basis of contact toxicity[10,11] and remedial efficacy[12] against other bark beetles. The treatments were chlorpyrifos (Dursban 4E), carbaryl (Sevimol 4), and fenitrothion (Sumithion 8E) each at 1, 2, and 4 pct active ingredient (a.i.), plus lindane at 0.6 pct a.i.—the registered treatment.[13] Dursban 4E at 2 pct a.i. is registered in southern California for remedial control of bark beetles. Twenty-two bolts from the 10 trees were randomly assigned as untreated checks: three bolts from each of 5 trees, two bolts from each of 2 trees, and one bolt from each of 3 trees.

Bolts were sprayed outdoors during the morning and early afternoon of June 30. About 1.9 liters of each treatment were mixed in plastic containers. The insecticide concentrates were diluted with tap water, unadjusted for pH. The treatments were applied with a nozzle that produced a fan-shaped spray, attached to a 1-liter stainless steel can and a low pressure electric air compressor. A bolt was set vertically on a cardboard box and sprayed to wetness with about 150 ml of insecticide per bolt. Treatments were applied in increasing strength of each chemical, and the sprayer was flushed with several rinses of water between chemicals.

After air-drying, each bolt was set vertically in a cardboard box (35.6 by 35.6 by 35.6 cm), which was then sealed with tape. Each box had a 3.8-cm-diameter hole cut in one side, with the center of the hole 5.1 cm below the top of the box. A plastic box (5.9 by 5.9 by 12.9 cm) with a 4.1-cm-diameter hole centered 3.8 cm below the top of the box was glued over the hole in the cardboard box. A 50 pct solution of antifreeze in water was put in the plastic boxes to a depth of 4 cm, to kill and preserve emerging insects. A 3.8-cm-diameter hole was cut in the lid of each plastic box and covered with a piece of fine mesh aluminum screen for ventilation. Cardboard boxes with bolts, segregated by treatment and control, were stacked two high on 10-cm-diameter wooden poles and tented over with a tarpaulin to shield them from rain, but not to impede air circulation. Untreated bolts were under the tarp with treated bolts, but stacked near an edge.

On September 13, 75 days later, *D. ponderosae* in the plastic emergence traps were counted. The cardboard boxes were opened and the bolts removed, and beetles on the bottom of the boxes were counted. Bark was peeled from the bolts, and beetles under the bark were counted. When more than one bolt from a tree was assigned to a treatment or the check, the numbers of beetles from these bolts were averaged to give one value per tree for each measurement.

The proportion of beetles in each plastic emergence trap was calculated for the treatments and the check, and a "survival ratio" of treatment to check was calculated from these proportions. The initial sample size of 11 was calculated on the basis of a null hypothesis that the survival ratio was 0.10 or greater, and an alternative hypothesis that the survival ratio was less than 0.10. A sample size of 11 could show a survival ratio of 0.07 or less with a power of 0.95 when alpha equals 0.05. A mean survival ratio and simultaneous one-sided 95 percent upper confidence limit was calculated for each treatment. Each of the other treatments was compared with lindane by calculating the mean difference between the survival ratios and constructing a simultaneous 95 percent confidence interval about each mean.[14] The Bonferroni *t* statistic[15] was used to construct confidence intervals so that the simultaneous Type I error rate—the probability that one or more of the intervals did not contain the true population mean—was at most 0.05.

RESULTS AND DISCUSSION

Averages of 4 to 27 percent of the *D. ponderosae* from the treated bolts and 71 percent of the beetles from the untreated bolts emerged into the plastic traps *(table 1)*. Although these beetles were dead when they were counted, I assumed that most would have been able to attack live trees had they not been trapped. All beetles on the bottom of the cardboard boxes were dead, as were most of the beetles found under the bark. The few live beetles under the bark were included in the tally of dead beetles.

While the survival ratios and one-sided upper confidence limits can be compared with a standard, these statistics do not allow multiple comparisons at the same 5 percent Type I error rate. In other words, the error rate is higher than 5 percent. For example, if the survival ratio of each treatment is compared with 0.1, the mean ratios of four of the treatments—lindane, chlorpyrifos at 2 and 4 pct a.i., and fenitrothion at 4 pct a.i.—were less than 0.1 *(table 1)*, but the upper confidence limit of only one treatment—chlorpyrifos at 4 pct a.i.—was less than 0.1.

Survival ratios for chlorpyrifos and fenitrothion at 4 pct a.i. were less than that for lindane, and survival ratios for

Table 1—*Emergence of* Dendroctonus ponderosae *from lodgepole pine bolts treated with insecticides, White River National Forest, Colorado, June 28 to September 19, 1983*

Treatment (pct active ingredient)	Emerged beetles[1]	Survival ratio[2]	Total beetles[3]
Check	0.709 (0.245)		1178
Lindane (0.6)	0.059 (0.070)	0.079 (0.173)	590
Chlorpyrifos (1)	0.114 (0.073)	0.294 (0.807)	567
Chlorpyrifos (2)	0.068 (0.069)	0.095 (0.205)	705
Chlorpyrifos (4)	0.035 (0.031)	0.044 (0.085)	584
Carbaryl (1)	0.269 (0.173)	0.384 (0.730)	801
Carbaryl (2)	0.155 (0.139)	0.210 (0.403)	686
Carbaryl (4)	0.105 (0.065)	0.220 (0.480)	740
Fenitrothion (1)	0.136 (0.116)	0.311 (0.790)	773
Fenitrothion (2)	0.081 (0.075)	0.104 (0.202)	905
Fenitrothion (4)	0.039 (0.047)	0.054 (0.121)	641

[1]Mean proportion (n=10) of beetles in plastic emergence trap. Standard deviations are in parentheses.

[2]Mean ratio (n=10) of proportion of beetles that emerged from treated bolts to proportion that emerged from check bolts. Simultaneous one-sided 95 percent upper confidence limits are in parentheses.

[3]In plastic trap, on bottom of cardboard box, and under bark.

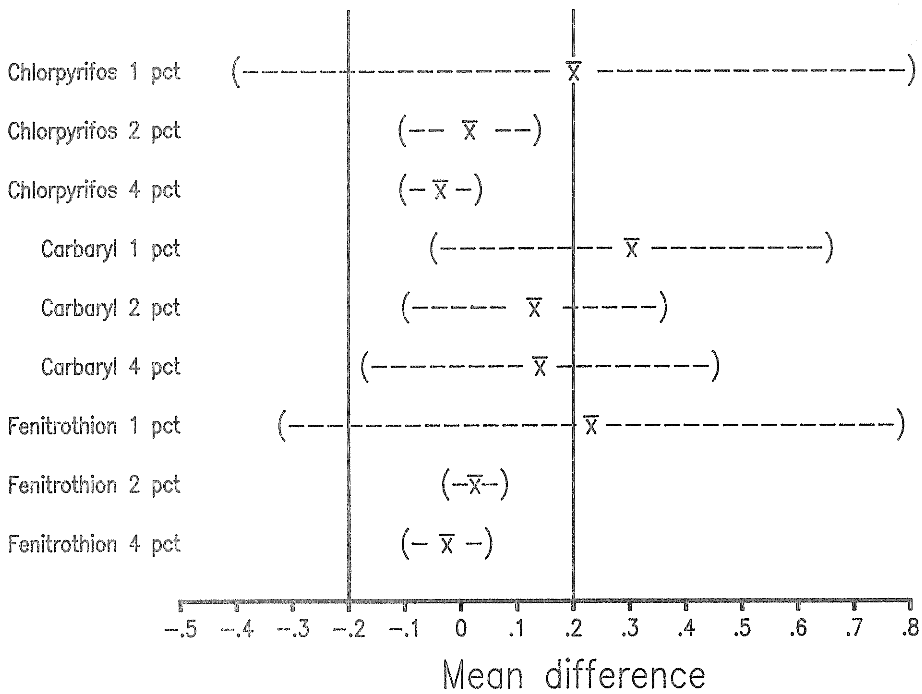

Figure 1—Mean differences in survival ratios and 95 percent simultaneous confidence intervals between nine insecticide treatments and lindane at 0.6 pct a.i. Two vertical lines delimit a mean difference of 0 ± 0.2 between lindane and another treatment.

the other seven treatments were greater than that for lindane *(table 1)*. If, for example, an absolute difference in survival ratios of 0.2 is biologically meaningful, then chlorpyrifos and fenitrothion at 2 and 4 pct a.i. did not differ from lindane, the three carbaryl treatments were not more effective than lindane, and the evidence for chlorpyrifos and fenitrothion at 1 pct was inconclusive *(fig. 1)*.

I examined the cardboard boxes that held the bolts and could find no beetle emergence holes. The plastic emergence traps appeared to be an efficient way to estimate emergence from a bolt, and to obtain a relative measure of the effectiveness of the treatments. Counting the number of beetles in the plastic traps may have overestimated the number of beetles able to fly and attack trees, because mortality of beetles held 48 to 72 hours after emergence from bolts treated with an insecticide is usually greater than that for beetles emerging from untreated bolts.[5,12] Shielding bolts from environmental effects, such as rain and external predators, may also have resulted in overestimation of emergence. Fumigation effects in the boxes could have resulted in underestimation of emergence from treated bolts.

CONCLUSIONS

Chlorpyrifos and fenitrothion at 2 and 4 pct a.i. were about as effective as lindane at the registered dosage of 0.6 pct a.i. in reducing emergence of mountain pine beetles from lodgepole pine. Other factors, such as cost, persistence, and effects on other organisms, should also be considered before recommending chemicals as alternatives to lindane for remedial control of bark beetles. In future studies, the width of confidence intervals could be reduced by increasing the sample size and by choosing a lower level of confidence, such as 90 percent.

NOTES

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[5]Stevens, Robert E.; Mitchell, James C. *Lindane spray effective against mountain pine beetle in the Rocky Mountains.* Res. Note RM-167. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1970. 4 p.

[6]This publication neither recommends the pesticide uses reported, nor implies that they have been registered by the appropriate governmental agencies.

[7]Federal Register. *Ethylene dibromide; intent to cancel registrations of pesticide products containing ethylene dibromide; determination concluding the Rebuttable Presumption Against Registration; availability of Position Document.* Fed. Regist. 48(197): 46234-46248; 1983 October 11.

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[12]Jones, A. S.; Hastings, F. L.; Kislow, C. J. *Evaluation of 12 insecticides for remedial efficacy against southern pine beetle adults.* J. Econ. Entomol. 73(5): 736-738; 1980 October.

[13]Dursban provided by Dow Chemical U.S.A., and Sumithion provided by Sumitomo Chemical America, Inc. Trade names and commercial enterprises are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

[14]Jones, Davy. *Use, misuse, and role of multiple-comparison procedures in ecological and agricultural entomology.* Environ. Entomol. 13(3): 635-649; 1984 June.

[15]Pages 67-70 in Miller, Rupert J., Jr. *Simultaneous statistical inference.* 2d ed. New York: Springer-Verlag; 1981. 299 p.

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