# RESIDUAL TOXICITY OF ELEVEN INSECTICIDE FORMULATIONS TO THE MOUNTAIN PINE CONE BEETLE, *CONOPHTHORUS MONTICOLAE* HOPKINS[1]

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## ABSTRACT

Adult mountain pine cone beetles were exposed to residues of eleven insecticide formulations. After 24 hours of exposure encapsulated resmethrin and fenvalerate were the most toxic, with $LC_{50}$ values 325 and 65 times as toxic, respectively, as the least toxic formulation, encapsulated fenitrothion.

Key Words: *Pinus monticola*, carbaryl, chlorpyrifos, diazinon, fenitrothion, fenvalerate, lindane, methyl parathion, permethrin, resmethrin, insecticides

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[1] This paper reports research involving chemical insecticides. It does not include recommendations for their use, nor does it imply that uses discussed here have been registered. All uses of insecticides must be registered by appropriate State or Federal agencies, or both, before they can be recommended.

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Periodically, cone crops of various species of *Pinus* are reduced severely by the activity of *Conophthorus* species. One of the most recent reports of severe seed crop losses because of infestations of cones by *C. monticolae* Hopkins occurred in a blister rust-resistant white pine (*Pinus monticola*) seed orchard at Sandpoint, Idaho. Because the seed from this orchard is valuable for establishing new seed orchards and for reforestation, the development of effective control methods is high priority. Mechanical control – removing the beetle-infested cones from the seed orchard – is not likely to be adequate because mature western white pines on adjoining private lands harbor beetle populations that could reinvade the orchard. Insecticide control seems to be the most reasonable strategy.

The biology of *C. monticolae*, as reported by Williamson *et al.* (1966), provides insight as to the appropriate chemical control strategy to use. Adult beetles usually overwinter in the aborted cones in which they have developed. Adult emergence, which occurs from early May until mid-June, coincides with the beginning of elongation of the second-year cones. Females bore into cones through the petiole or the basal scales, completely severing the conductive tissue in as few as 30 minutes. As soon as the conductive tissue is severed, the cone is functionally dead and will undergo no further development. After laying the initial batch of eggs in a gallery along the cone axis, the female may leave the cone and attack one or more additional cones. Several broods per season, but only one generation per year, are usual.

The behavior of *C. monticolae* from emergence until cone attack is unknown, but Godwin and Odell (1965), working with *C. coniperda*, observed that often adult beetles emerge then fly to the crowns of nearby white pines and that the lapsed time between the first observed spring emergence and the initial cone attack was 24 hours. In addition, emergence was synchronous for a large area so that the dispersal flight was short with the females spending little time on the foliage or feeding on other than second-year cones. Assuming *C. monticolae* behaves similarly, if damage to white pine cones is to be minimized, female beetles must be killed or repelled during the short period of time involved before they sever the conductive tissue. The chemical control strategy with the highest probability of success, therefore, would be a contact insecticide that acts rapidly and has a substantial residual life, or that can be reapplied one or more times during the flight season of *C. monticolae.*

This paper reports a laboratory test to determine the residual toxicity of 11 insecticide formulations to the mountain cone beetle. On the basis of the results four insecticides appear to be suitable candidates for field testing.

## METHODS AND MATERIALS

Insecticides used in this experiment were carbaryl [Sevin XLR (4 lb/gal EC)], chlorpyrifos [Dursban (4 lb/gal EC)], diazinon [Spectracide (4 lb/gal EC)] and Knoxout 2FM (microencapsulated at 23% a.i.)] , lindane [Isotox (1.65 lb/gal EC)], methyl parathion [Pencap-M (microencapsulated at 22% a.i.)], permethrin [Pounce (3.2 lb/gal EC)], resmethrin [microencapsulated at 3% a.i.], and fenvalerate (Pydrin (2.4 lb/gal EC)]. All insecticides were formulated in distilled water. For each insecticide formulation, eight dilutions were prepared individually in small volumes (5-10 ml) in concentrations equivalent to lbs a.i./100 gal water. One ml of each solution was applied to a separate piece of filter paper (Whatman) in the lid of a 90 x 15 mm plastic petri dish, and allowed to dry in a fume hood for 2 to 4 hours. After the filter paper had dried, the petri dish bottoms were replaced. The eight petri dishes containing filter papers treated with the same insecticides were placed in a plastic bag, and stored in a freezer until used.

Adult male and female beetles were collected in cones from the white pine seed orchard on the Sandpoint Ranger District, Idaho Panhandle National Forest, Sandpoint, Idaho. Beetles were removed from the cones by hand and placed in petri dishes lined with filter paper. The filter paper was moistened with distilled water to prevent dehydration of the beetles. Petri dishes were held for 1 to 2 days at 5 C, until enough beetles had been collected to complete one replication. Before each test, beetles were transferred from the petri dishes into individual 1-oz (29.6-ml) plastic jelly cups with paper lids. Twenty beetles were placed in each cup.

The experiment was replicated four times. For each replication, one half of the 92 petri plates (eight concentrations of 11 formulations and 4 controls) were selected at random for testing on the first day. The remainder were tested on the next day. Beetles from a randomly selected jelly cup were placed on the treated filter paper within the petri dish lid. A wide-mouth canning jar lid with a wire screen insert was placed on top of the filter paper to contain the beetles on the treated filter paper and yet provide ventilation. Each 24-hour experiment was conducted in an operating fume hood to prevent insecticide vapors from accumulating in the air space immediately above the treated filter paper. Dead and moribund insects were removed and their number recorded at 12 and 24 hours after the beetles had been placed on the paper. A beetle was considered moribund, irreversibly approaching death, when it could no longer right itself and walk. Data were analyzed by probit analysis (Russell *et al.* 1977). For each insecticide formulation, $LC_{50}$ and $LC_{90}$ values at 12 and 24 hours were calculated and selected regression lines compared by likelihood ratio tests (Savin *et al.* 1977).

## RESULTS AND DISCUSSION

The responses of *C. monticolae* to the eleven insecticide formulations were compared at 12 and 24 hours (Tables 1 and 2, and Figure 1). The decreasing order of relative toxicity at the $LC_{50}$ at 12 hours (index of relative toxicity = $LC_{50}$ for the least toxic formulation, encapsulated fenitrothion, divided by the $LC_{50}$ for formulation X) of the 11 formulations was: encapsulated resmethrin, 45; fenvalerate, 30; lindane, 15; permethrin, 10; carbaryl, 9; chlorpyrifos, 5.6; encapsulated m-parathion, 4.5; encapsulated diazinon, 4.3; diazinon, 2.2; and fenitrothion, 1.0. The decreasing order of relative toxicity at 24 hours was: encapsulated resmethrin, 325; fenvalerate, 65; lindane, 16.3; chlorpyrifos, 13.0; permethrin, 13.0; encapsulated diazinon, 7.2; carbaryl, 7.2; encapsulated m-parathion, 4.6; diazinon, 3.8; and fenitrothion, 1.4.

Encapsulated diazinon was 1.7 to 2.0 times more toxic than the emulsifiable concentrate of diazinon, and the response curves for these two formulations were not parallel. The slope of the encapsulated diazinon curve was steeper than that of the emulsion, perhaps because the emulsified diazinon

Table 1. – Toxicity of insecticide formulations (lbs a.i./100 gal water) to adult *Conophthorus monticolae* at 12 hours.

| Insecticide formulation | Insects treated[a] | Slope±S.E. | $LC_{50}$ | 95% CL | $LC_{90}$ | 95% CL | Toxicity index[b] |
|---|---|---|---|---|---|---|---|
| Resmethrin (encap.) | 626 | 1.41±0.19 | 0.02 | 0.00-0.03[c] | 0.16 | 0.09-0.68[c] | 45 |
| Fenvalerate | 638 | 2.04±0.17 | 0.03 | 0.02-0.04 | 0.11 | 0.07-0.33 | 30 |
| Lindane | 597 | 2.03±0.16 | 0.06 | 0.04-0.09 | 0.26 | 0.17-0.53 | 15 |
| Permethrin | 632 | 3.10±0.41 | 0.09 | 0.04-0.12 | 0.22 | 0.15-1.40 | 10 |
| Carbaryl | 575 | 6.91±1.17 | 0.10[d] | – | 0.16[d] | – | 9 |
| Chlorpyrifos | 635 | 3.47±0.60 | 0.16[d] | – | 0.39[d] | – | 5.6 |
| m-Parathion (encap.) | 631 | 2.97±0.39 | 0.20 | 0.10-0.26[c] | 0.55 | 0.42-1.47[c] | 4.5 |
| Diazinon (encap.) | 629 | 8.91±1.30 | 0.21[d] | – | 0.28[d] | – | 4.3 |
| Diazinon | 751 | 3.71±0.31 | 0.41 | 0.24-0.54 | 0.91 | 0.68-2.03 | 2.2 |
| Fenitrothion | 622 | 4.49±0.37 | 0.90 | 0.74-1.05 | 1.73 | 1.41-2.52 | 1.0 |
| Fenitrothion (encap.) | 624 | 3.84±0.47 | 0.90 | 0.65-1.27[c] | 1.94 | 1.34-7.41 | – |

[a]Control mortality was 3.2%.

[b]Toxicity index = $LC_{50}$ of encapsulated fenitrothion ÷ $LC_{50}$ of insecticide formulation X.

[c]90% CL.

[d]Confidence limits not computed because the value of the confidence coefficient exceeded 0.5 at the $a$ = .90 level.

Table 2. – Toxicity of insecticide formulations (lb a.i./100 gal water) to adult *Conophthorus monticolae* at 24 hours.

| Insecticide formulation | Insects treated[a] | Slope±S.E. | $LC_{50}$ | 95% CL | $LC_{90}$ | 95% CL | Toxicity index[b] |
|---|---|---|---|---|---|---|---|
| Resmethrin (encap.) | 626 | 1.14±0.31 | 0.002[d] | – | 0.03[d] | – | 325 |
| Fenvalerate | 638 | 2.25±0.18 | 0.01 | 0.01-0.02 | 0.05 | 0.03-0.11 | 65 |
| Lindane | 617 | 2.70±0.28 | 0.04 | 0.03-0.05 | 0.13 | 0.10-0.19 | 16.3 |
| Chlorpyrifos | 635 | 3.08±0.32 | 0.05 | 0.04-0.06 | 0.13 | 0.10-0.22 | 13.0 |
| Permethrin | 632 | 2.30±0.19 | 0.05 | 0.03-0.08 | 0.19 | 0.12-0.63 | 13.0 |
| Diazinon (encap.) | 629 | 2.83±0.27 | 0.09 | 0.04-0.12 | 0.24 | 0.17-0.81 | 7.2 |
| Carbaryl | 635 | 6.84±1.18 | 0.09[d] | – | 0.15[d] | – | 7.2 |
| m-Parathion (encap.) | 631 | 4.58±0.53 | 0.14 | 0.07-0.19 | 0.28 | 0.23-0.35 | 4.6 |
| Diazinon | 748 | 4.06±0.46 | 0.17 | 0.09-0.23 | 0.35 | 0.28-0.51 | 3.8 |
| Fenitrothion | 622 | 10.66±1.29 | 0.45 | 0.39-0.49 | 0.59 | 0.54-0.72 | 1.4 |
| Fenitrothion (encap.) | 624 | 3.70±0.49 | 0.65 | 0.35-0.86[c] | 1.43 | 1.02-6.58[c] | – |

[a]Control mortality was 4.6%.

[b]Toxicity index = $LC_{50}$ of encapsulated fenitrothion ÷ $LC_{50}$ of insecticide formulation X.

[c]90% CL.

[d]Confidence limits not computed because the value of the confidence coefficient exceeded 0.5 at the $\alpha = .90$ level.

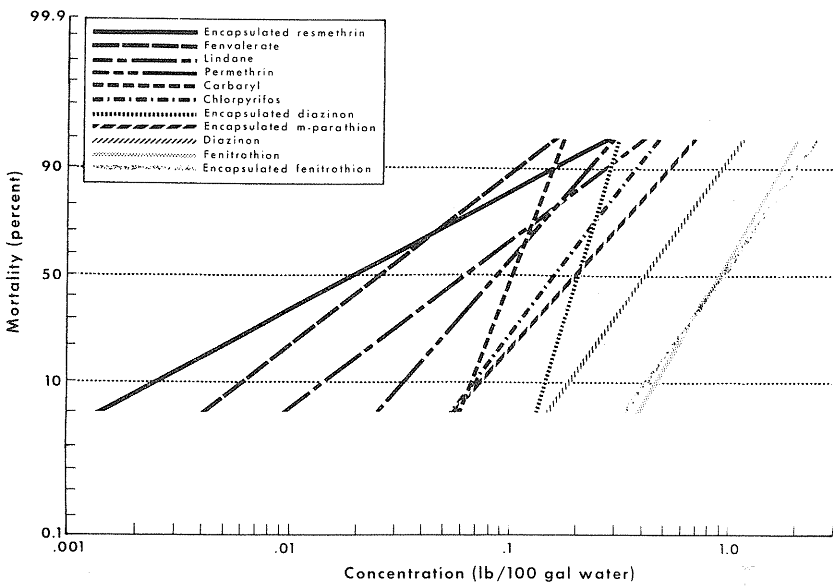


Fig. 1. – Response of *Conophthorus monticolae* to 11 insecticide formulations after 12-hour exposure.

was adsorbed by the filter paper and was less available to the beetles. The encapsulated material was not adsorbed.

Both emulsifiable and encapsulated fenitrothion had the same $LC_{50}$ value at 12 hours, but were quite different at 24 hours. Their response curves were equal at 12 hours, but were neither equal nor parallel at 24 hours. A comparison of the encapsulated and emulsifiable fenitrothion showed a response opposite to that of the two formulations of diazinon. If our interpretation of diazinon's behavior is correct, fenitrothion is probably not adsorbed by the filter paper as is diazinon. Beetles, therefore, are exposed to more toxicant when it is applied as an emulsion than as a suspension of small fenitrothion-filled capsules.

The susceptibility of *C. monticolae* within 12 hours to low concentrations of several of the formulations encouraged us in the possibility that a chemical control strategy can be developed. It may have been more helpful to have a method of analysis that could provide an estimate of the concentration required to kill 90 percent of the insects within 1-2 hours. Such a method would allow us to make better choices for application rates to test in the field. If sufficiently toxic residues can be maintained on the crown of white pines from early May until mid-June, however, cones should be protected from attack by *C. monticolae*. With compounds such as fenvalerate, lindane, permethrin, and carbaryl, each of which has a long residual life, it should be possible to apply small quantities (0.5 - 1.0 lb/100 gal water) of insecticides once or twice to achieve at least 90 percent protection of the cones.

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