# COMPARATIVE TOXICITY OF INSECTICIDES TO *CHORISTONEURA* SPECIES (LEPIDOPTERA: TORTRICIDAE)

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**Abstract**

Selected carbamate, chlorinated hydrocarbon, organophosphorous, and pyrethroid insecticides were tested on six *Choristoneura* species: *conflictana* (Walker), *fumiferana* (Clemens), *lambertiana ponderosana* Obraztsov, *occidentalis* Freeman, *pinus* Freeman, and *viridis* Freeman. When probit regression lines were compared by likelihood ratio tests, the hypothesis of equality was uniformly rejected. The hypothesis of parallelism was accepted for some chemicals within each insecticide class except the chlorinated hydrocarbon. These results suggest that extrapolating the response of one species to another species should be avoided.

Species in the genus *Choristoneura* number among the most destructive forest insect pests in North America (McKnight 1968). It is of practical interest to know the extent of variation in responses of the various *Choristoneura* species to insecticides being developed for forest insect control. Commonly, if no insecticides have been tested on a particular species, results of tests on other species in the same genus are used to estimate the responses of untested species. To determine the accuracy of such extrapolation, we compared the responses of six *Choristoneura* species to selected insecticides.

The six species we tested and their primary hosts are: *C. fumiferana* (Clemens) — balsam fir, *Abies balsamea* (L.) Mill.; western spruce budworm, *C. occidentalis* Freeman — Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco; jack pine budworm, *C. pinus* Freeman — jack pine, *Pinus banksiana* Lamb., and red pine, *P. resinosa* Ait.; *C. viridis* Freeman — white fir, *A. concolor* (Gord. and Glend.) Lindl., and grand fir, *A. grandis* (Dougl.) Lindl.; large aspen tortrix, *C. conflictana* (Walker) — quaking aspen, *Populus tremuloides* Michx.; and *C. lambertiana ponderosana* — sugar pine, *P. lambertiana* Dougl.

## Materials and Methods

*C. occidentalis, fumiferana, pinus,* and *viridis* were obtained from nondiapausing laboratory colonies reared on artificial diet (Lyon *et al.* 1972). Diapausing *C. conflictana* were collected from the north rim of the Grand Canyon in Arizona, shipped to Berkeley, Calif., refrigerated 60–90 days at 5°C, then brought to room temperature for subsequent development. They were fed artificial diets during their postdiapause development. *C. lambertiana ponderosana*[6] were received as feeding larvae from Ft. Collins, Colo., in 2 successive years, transferred to artificial diet, and used for testing. Some were used to establish a nondiapausing laboratory colony which provided sufficient insects to complete the testing. Last instars of all species were used in the tests.

The years during which tests were conducted varied.[7] They were *C. occidentalis,* 1967–75; *C. fumiferana,* 1968; *C. pinus,* 1968; *C. viridis,* 1970–76; *C. conflictana,*

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[7]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.

Table I. Comparative toxicity of carbamate insecticides to *Choristoneura* species[a]

| Species[b] | N | NC | C±S.E. | Beta±S.E. | $LD_{50}$ | 95% CL | $LD_{90}$ | 95% CL | HET | Log L |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | - - - - - - - - - - - - $\mu$g/g body weight - - - - - - - - - - - - | | | | | |
| | | | | | **A. Aminocarb** | | | | | |
| O | 150 | 30 | 0.035±0.034 | 2.37±0.44 | 1.24 | 0.88–1.60 | 4.31 | 3.09–8.02 | 0.72 | −74.7 |
| V | 398 | 30 | 0±0 | 1.98±0.28 | 6.65 | 4.74–14.6 | 29.4 | 13.8–288 | 1.35 | −203.5 |
| | | | | | **B. Carbaryl** | | | | | |
| C | 219 | 22 | 0±0 | 2.46±0.38 | 3.65 | 2.92–4.35 | 12.1 | 9.27–19.2 | 0.05 | −117.2 |
| O | 310 | 30 | 0±0 | 2.20±0.22 | 19.9 | 14.5–26.5 | 76.0 | 51.6–148 | 1.03 | −147.4 |
| L | 409 | 735 | 0.022±0.005 | 2.53±0.31 | 30.6 | 11.5–44.5 | 98.3 | 69.0–236 | 3.29 | −232.9 |
| V | 402 | 31 | 0±0 | 1.49±0.22 | 109 | 6.90–325 | 791 | 282–1420 | 1.02 | −195.6 |
| | | | | | **C. Methomyl** | | | | | |
| C | 257 | 30 | 0.042±0.042 | 2.02±0.32 | 2.02 | *c* | 8.73 | *c* | 3.07 | −147.9 |
| O | 410 | 50 | 0.021±0.020 | 0.94±0.12 | 2.44 | 1.54–3.49 | 55.3 | 31.5–132 | 0.73 | −238.2 |
| V | 399 | 30 | 0±0 | 1.61±0.24 | 4.87 | 3.40–10.1 | 30.5 | 12.0–52.5 | 1.39 | −239.5 |
| L | 359 | 735 | 0.022±0.005 | 1.39±0.22 | 7.51 | 4.13–10.7 | 62.5 | 13.0–52.5 | 0.54 | −245.4 |
| | | | | | **D. Mexacarbate** | | | | | |
| P | 600 | 80 | 0.053±0.026 | 2.45±0.21 | 0.93 | 0.65–1.21 | 3.11 | 2.35–4.85 | 1.32 | −289.8 |
| O | 445 | 118 | 0.008±0.008 | 2.45±0.22 | 0.94 | 0.80–1.09 | 3.14 | 2.63–3.96 | 0.24 | −208.3 |
| F | 587 | 80 | 0.039±0.022 | 2.61±0.22 | 1.20 | 1.03–1.36 | 3.72 | 3.18–4.53 | 0.17 | −291.1 |
| L | 549 | 43 | 0±0 | 1.82±0.19 | 1.98 | 1.61–2.33 | 10.0 | 7.92–14.0 | 0.64 | −300.9 |
| V-71 | 444 | 116 | 0.058±0.023 | 2.40±0.33 | 2.45 | 2.05–2.88 | 8.41 | 6.39–13.2 | 0.51 | −269.5 |
| V-76 | 450 | 90 | 0±0 | 2.87±0.26 | 2.66 | 2.05–3.69 | 7.44 | 4.94–18.2 | 2.05 | −206.7 |
| C | 250 | 13 | 0±0 | 4.30±0.45 | 3.41 | 2.01–4.73 | 6.77 | 4.86–18.2 | 3.41 | −103.9 |

[a]Column headings are abbreviated as follows: N is the number of insects treated with insecticide; NC is the number of controls; C±S.E. is estimated control mortality ± the standard error; Beta±S.E. is the slope ± the standard error; HET is the heterogeneity factor; and Log L the maximum log-likelihood function.
[b]C = *conflictana*; F = *fumiferana*; L = *lambertiana ponderosana*; O = *occidentalis*; P = *pinus*; V = *viridis*. Numbers after V indicate year of test.
[c]No confidence limits computed because g ≥ 0.50 at 95% level.

1973–74; *C. lambertiana ponderosana,* 1974–75. Tests of mexacarbate, pyrethrins, and DDT on *C. viridis* were repeated in 1971 and 1976. All insecticides were not tested on all species because of the nonsynchronous availability of insects and insecticides. However, all six species were tested with mexacarbate, which is registered for control of *C. fumiferana, occidentalis,* and *pinus* (Anon. 1974), and with DDT, which was the chemical most widely used in past control programs. One insecticide without a common name, NRDC 161 (3-phenoxybenzyl (±)-3-(2,2-dibromovinyl)-2,2-dimethylcyclopranecarboxylate), was also tested.

Procedures for formulation and topical application were described by Robertson *et al.* (1976). Data from mortality counts made 7 days after treatment were analyzed by probit analysis (Russell *et al.* 1977) and the regression lines compared by likelihood ratio tests (Savin *et al.,* in press).

## Results and Discussion

Response of the species to carbamate insecticides (Table I) varied widely. Of the six species tested with mexacarbate, *C. pinus* was most susceptible at $LD_{50}$, *C. conflictana* least susceptible. Neither parallelism nor equality of response was observed among the six species (Table V). The responses of *C. viridis* tested in 1971 and 1976 were both parallel ($p = 0.220$) and equal ($p = 0.267$).

Carbaryl and methomyl were tested on *C. conflictana, lambertiana ponderosana, occidentalis,* and *viridis. C. conflictana* was most susceptible to both these carbamates, while *viridis* was least susceptible to carbaryl, and *lambertiana ponderosana* least susceptible to methomyl (Table I). As in the test with mexacarbate, the responses of the species to carbaryl and methomyl were neither parallel nor equal. The responses of *C. occidentalis* and *C. viridis* to aminocarb were parallel but not equal (Table V).

*C. occidentalis* was most susceptible to the chlorinated hydrocarbon DDT, *C. lambertiana ponderosana* least susceptible (Table II). The responses of the six species tested were neither parallel nor equal (Table V), nor were the responses of *C. viridis* tested in 1971 and 1976 (parallelism: $p = 0.000$; equality: $p = 0.000$).

Four species (*conflictana, lambertiana ponderosana, occidentalis, viridis*) were tested with the organophosphorous compounds acephate, chlorpyrifos, chlorpyrifos-methyl, fenitrothion, malathion, phosmet, phoxim, and trichlorfon (Table III). The species most susceptible to each compound at $LD_{50}$ were: *viridis,* acephate; *occidentalis,* chlorpyrifos; *lambertiana ponderosana,* fenitrothion; *lambertiana ponderosana,* chlorpyrifos-methyl; *conflictana,* malathion; *viridis,* phosmet; *lambertiana ponderosana,* phoxim; *occidentalis,* tetrachlorvinfos; and *conflictana,* trichlorfon. For each insecticide, the least susceptible species were *conflictana,* acephate; *viridis,* chlorpyrifos; *viridis,* chlorpyrifos-methyl; *conflictana,* fenitrothion; *occidentalis,* malathion; *occidentalis,* phosmet; *viridis,* phoxim; *conflictana,* tetrachlorvinfos; and *lambertiana ponderosana,* trichlorfon. Thus, no single species was consistently the most or least susceptible at $LD_{50}$. Comparisons of the regression lines for these compounds showed no equality (Table V). Parallelism, however, was demonstrated with chlorpyrifos and chlorpyrifos-methyl. *C. occidentalis* and *viridis* were tested with the organophosphorous compounds chlorphoxim and fenthion. In both cases, *C. occidentalis* was the more susceptible. Parallelism of response to chlorphoxim was observed, but not to fenthion. Responses of the two species to the two chemicals were not equal.

*C. conflictana* was the most susceptible of the five species tested with pyrethrins, *viridis* the least susceptible (Table IV). Although neither parallelism nor equality in response among the five species was demonstrated (Table V), the two tests conducted with *C. viridis* showed parallel and equal responses (parallelism: $p = 0.260$; equality: $p = 0.057$). Four species (*conflictana, lambertiana ponderosana, occidentalis, viridis*)

Table II. Comparative toxicity of a chlorinated hydrocarbon, DDT, to *Choristoneura* species[a]

| Species[b] | N | NC | C±S.E. | Beta±S.E. | $LD_{50}$ | 95% CL | $LD_{90}$ | 95% CL | HET | Log L |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | μg/g body weight | | | | | |
| O | 425 | 119 | 0.009±0.009 | 2.71±0.27 | 18.5 | *c* | 55.0 | *c* | 5.27 | −213.5 |
| P | 600 | 80 | 0.050±0.024 | 0.78±0.18 | 24.5 | 15.1–35.3 | 1070 | 349–18400 | 0.52 | −418.6 |
| C | 316 | 25 | 0±0 | 2.31±0.25 | 28.8 | 24.6–33.7 | 103 | 79.7–151 | 0.74 | −168.4 |
| V-76 | 450 | 30 | 0±0 | 2.80±0.24 | 34.1 | 22.0–57.7 | 97.9 | 57.8–591 | 4.70 | −228.3 |
| V-71 | 443 | 116 | 0.049±0.019 | 1.62±0.24 | 49.4 | *c* | 30.7 | *c* | 2.94 | −296.1 |
| F | 600 | 80 | 0.034±0.019 | 1.61±0.21 | 56.0 | 40.5–91.1 | 349 | 171–1940 | 1.09 | −372.3 |
| L | 261 | 29 | 0.028±0.027 | 1.98±0.35 | 121 | *c* | 537 | *c* | 1.61 | −158.9 |

[a]For explanation of column headings, see footnote *a* in Table I.
[b]C = *conflictana*; F = *fumiferana*; L = *lambertiana ponderosana*; O = *occidentalis*; V = *viridis*. Numerals after V indicate year of test.
[c]No confidence limits computed because g ≥ 0.50 at 95% level.

Table III. Comparative toxicity of organophosphorous insecticides to *Choristoneura* species[a]

| Species[b] | N | NC | C±S.E. | Beta±S.E. | $LD_{50}$ | 95% CL | $LD_{90}$ | 95% CL | HET | Log L |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | μg/g body weight | | | | | |
| | | | | **A. Acephate** | | | | | | |
| V | 450 | 30 | 0±0 | 2.30±0.26 | 23.8 | 18.5–28.6 | 85.7 | 72.1–108 | 0.58 | −178.9 |
| L | 319 | 735 | 0.022±0.005 | 3.72±0.45 | 25.7 | 21.8–29.1 | 56.7 | 49.2–69.2 | 0.50 | −189.3 |
| O | 240 | 874 | 0.049±0.007 | 3.68±0.49 | 29.7 | 25.0–34.4 | 60.0 | 50.0–78.1 | 0.84 | −240.8 |
| C | 270 | 15 | 0±0 | 3.21±0.33 | 43.7 | *c* | 110. | *c* | 4.93 | −111.4 |
| | | | | **B. Chlorphoxim** | | | | | | |
| O | 159 | 30 | 0±0 | 4.34±0.61 | 1.99 | 1.69–2.38 | 3.92 | 3.13–5.56 | 0.04 | −40.9 |
| V | 257 | 40 | 0±0 | 4.04±0.45 | 3.44 | 2.11–5.13 | 7.15 | 4.89–36.6 | 2.08 | −129.2 |
| | | | | **C. Chlorpyrifos** | | | | | | |
| O | 140 | 20 | 0.088±0.049 | 4.35±0.76 | 2.66 | 2.05–3.25 | 5.25 | 4.24–7.30 | 0.28 | −58.2 |
| C | 310 | 38 | 0±0 | 3.24±0.34 | 3.42 | 2.10–4.70 | 8.51 | 5.89–23.9 | 2.84 | −157.3 |
| L | 99 | 359 | 0.020±0.007 | 3.68±0.70 | 4.67 | 3.51–5.72 | 10.4 | 8.24–15.8 | 0.18 | −74.0 |
| V | 500 | 32 | 0±0 | 4.27±0.37 | 5.81 | 5.33–6.37 | 11.6 | 10.1–13.9 | 0.97 | −151.3 |
| | | | | **D. Chlorpyrifos-Methyl** | | | | | | |
| L | 527 | 735 | 0.022±0.005 | 3.47±0.30 | 1.67 | 1.47–1.85 | 3.91 | 3.48–4.53 | 0.78 | −273.5 |
| O | 120 | 20 | 0±0 | 3.25±0.47 | *d* | *d* | *d* | *d* | 28.54 | −39.8 |
| C | 296 | 22 | 0±0 | 3.76±0.39 | 3.51 | 2.76–4.23 | 7.71 | 6.14–11.5 | 1.18 | −133.0 |
| V | 403 | 28 | 0±0 | 3.32±0.30 | 3.70 | *c* | 9.00 | *c* | 8.13 | −189.1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **E. Fenthion** | | | | | |
| O | 120 | 20 | 0±0 | 2.06±0.34 | 15.9 | 11.5–23.0 | 66.5 | 40.1–161 | 0.95 | −47.8 |
| V | 249 | 10 | 0±0 | 5.59±0.69 | 27.6 | *c* | 46.8 | *c* | 3.87 | −78.5 |
| | | | | | **F. Fenitrothion** | | | | | |
| L | 260 | 735 | 0.023±0.006 | 4.58±0.58 | 4.50 | 3.16–5.72 | 8.58 | 6.56–17.5 | 2.44 | −187.5 |
| O | 150 | 30 | 0.078±0.028 | 6.15±1.06 | 5.10 | 3.89–6.20 | 8.24 | 6.79–10.5 | 0.97 | −50.3 |
| V | 400 | 30 | 0±0 | 4.84±0.42 | 6.16 | 4.03–8.92 | 11.3 | 8.11–40.4 | 5.82 | −157.6 |
| C | 247 | 30 | 0±0 | 2.93±0.40 | 6.31 | 5.49–7.46 | 17.3 | 13.1–27.4 | 0.41 | −127.7 |
| | | | | | **G. Malathion** | | | | | |
| C | 324 | 30 | 0±0 | 2.93±0.31 | 10.2 | 7.68–13.8 | 28.0 | 19.9–66.6 | 1.69 | −156.6 |
| V | 395 | 28 | 0±0 | 2.06±0.24 | 14.1 | 11.0–16.9 | 59.1 | 47.4–81.6 | 0.75 | −192.0 |
| L | 140 | 359 | 0.019±0.007 | 3.89±0.64 | 28.6 | 23.4–33.6 | 61.1 | 50.0–85.4 | 0.08 | −90.9 |
| O | 360 | 80 | 0.013±0.012 | 2.38±0.25 | 24.5 | 20.5–28.7 | 84.6 | 67.7–115 | 0.44 | −168.9 |
| | | | | | **H. Phosmet** | | | | | |
| V | 400 | 30 | 0.067±0.046 | 3.11±0.37 | 6.44 | 5.31–7.47 | 16.6 | 14.1–21.0 | 0.44 | −186.6 |
| L | 76 | 359 | 0.020±0.007 | 3.61±0.89 | 11.7 | 7.42–15.0 | 26.6 | 20.5–45.7 | 0.58 | −63.5 |
| C | 322 | 35 | 0±0 | 3.41±0.36 | 19.0 | 16.2–21.7 | 45.2 | 39.1–54.9 | 0.87 | −118.2 |
| O | 400 | 59 | 0.049±0.027 | 2.17±0.22 | 37.8 | 30.2–45.6 | 148 | 117–201 | 0.67 | −202.9 |
| | | | | | **I. Phoxim** | | | | | |
| L | 567 | 735 | 0.022±0.005 | 3.34±0.28 | 1.92 | 1.72–2.12 | 4.65 | 4.13–5.41 | 0.50 | −312.7 |
| O | 539 | 50 | 0.011±0.011 | 4.11±0.31 | 2.33 | 1.46–3.29 | 4.77 | 3.36–12.1 | 5.57 | −191.4 |
| C | 208 | 22 | 0±0 | 3.49±0.48 | 3.06 | 2.10–3.87 | 7.12 | 5.42–12.6 | 1.42 | −88.3 |
| V | 450 | 40 | 0±0 | 5.32±0.42 | 3.22 | 2.49–3.97 | 5.61 | 4.47–8.92 | 3.25 | −150.0 |
| | | | | | **J. Tetrachlorvinfos** | | | | | |
| O | 240 | 30 | 0.030±0.021 | 2.86±0.31 | 25.5 | *c* | 71.5 | *c* | 3.76 | −95.2 |
| V | 471 | 50 | 0±0 | 1.84±0.33 | *d* | *d* | *d* | *d* | 2.73 | −217.8 |
| L | 297 | 735 | 0.022±0.005 | 1.80±0.21 | 35.0 | 19.1–52.6 | 181 | 110–507 | 1.67 | −215.9 |
| C | 90 | 10 | 0±0 | *e* | >100 | *e* | *e* | *e* | *e* | *e* |
| | | | | | **K. Trichlorfon** | | | | | |
| C | 302 | 31 | 0±0 | 4.43±0.46 | 17.7 | 13.7–21.8 | 34.4 | 27.0–54.8 | 1.52 | −99.2 |
| O | 319 | 368 | 0.016±0.007 | 2.44±0.25 | 20.0 | 11.8–29.2 | 66.8 | 42.7–187 | 1.16 | −179.2 |
| V | 348 | 34 | 0±0 | 3.39±0.33 | 20.0 | 15.9–24.4 | 47.7 | 36.9–74.2 | 1.16 | −142.6 |
| L | 170 | 359 | 0.020±0.007 | 3.60±0.53 | 35.6 | 27.9–42.5 | 80.8 | 66.9–106 | 0.43 | −91.4 |

[a]For explanation of column headings, see footnote *a* in Table I.
[b]C = *conflictana*; L = *lambertiana ponderosana*; O = *occidentalis*; V = *viridis*.
[c]No confidence limits computed because g ≥ 0.50 at 95% level.
[d]No $LD_{50}$ or $LD_{90}$ values or their respective confidence limits computed because g ≥ 0.50 at 90% level.
[e]Test suspended because less than 50% kill was achieved at highest dose level applied (100 μg/g body weight).

Table IV. Comparative toxicity of pyrethroid insecticides to *Choristoneura* species[a]

| Species[b] | N | NC | C±S.E. | Beta±S.E. | $LD_{50}$ | 95% CL | $LD_{90}$ | 95% CL | HET | Log L |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | μg/g body weight | | | | | |
| **A. Bioethanomethrin** | | | | | | | | | | |
| O | 258 | 874 | 0.049±0.007 | 3.72±0.48 | 0.091 | 0.079–0.104 | 0.20 | 0.17– 0.26 | 0.11 | −277.0 |
| C | 367 | 30 | 0±0 | 2.93±0.39 | *d* | *d* | *d* | *d* | 7.16 | −143.9 |
| V | 282 | 24 | 0±0 | 2.80±0.33 | 0.15 | 0.10–0.20 | 0.44 | 0.31– 0.97 | 1.50 | −156.9 |
| L | 224 | 359 | 0.019±0.007 | 3.00±0.40 | 0.37 | 0.30–0.43 | 0.98 | 0.80– 1.33 | 0.90 | −148.2 |
| **B. NRDC-161** | | | | | | | | | | |
| O | 450 | 30 | 0±0 | 2.93±0.37 | 0.0090 | 0.0047–0.0122 | 0.025 | 0.019– 0.039 | 1.36 | −128.0 |
| V | 450 | 30 | 0.048±0.047 | 3.15±0.37 | 0.022 | 0.018–0.025 | 0.055 | 0.047– 0.068 | 0.070 | −208.1 |
| **C. Permethrin** | | | | | | | | | | |
| O | 220 | 30 | 0±0 | 2.18±0.19 | 0.28 | 0.19–0.38 | 1.07 | 0.71– 2.37 | 1.89 | −228.96 |
| V | 450 | 30 | 0±0 | 2.32±0.23 | 0.47 | 0.26–0.69 | 1.68 | 1.04– 6.76 | 3.13 | −229.0 |
| **D. Phenothrin** (+ *cis*) | | | | | | | | | | |
| O | 340 | 40 | 0.016±0.016 | 2.65±0.24 | 0.26 | 0.18–0.36 | 0.78 | 0.53– 1.54 | 1.86 | −140.1 |
| V | 419 | 50 | 0±0 | 2.00±0.21 | 0.43 | 0.25–0.68 | 1.89 | 1.06–10.43 | 2.79 | −230.3 |
| C | 335 | 55 | 0.017±0.017 | 1.62±0.23 | 0.52 | 0.34–0.99 | 3.23 | 1.46–32.1 | 1.25 | −201.4 |
| L | 260 | 735 | 0.022±0.005 | 2.32±0.37 | 0.61 | 0.47–0.74 | 2.19 | 1.67– 3.48 | 0.84 | −199.8 |
| **E. Pyrethrins** | | | | | | | | | | |
| C | 247 | 14 | 0±0 | 3.16±0.43 | 0.72 | *c* | 1.82 | *c* | 3.17 | −105.9 |
| O | 440 | 118 | 0.008±0.009 | 1.57±0.15 | 0.86 | 0.70–1.05 | 5.68 | 4.06– 9.12 | 0.43 | −247.8 |
| F | 449 | 29 | 0.131±0.049 | 2.62±0.41 | 1.05 | 0.74–1.31 | 3.24 | 2.60– 4.54 | 0.91 | −224.9 |
| L | 725 | 64 | 0.030±0.021 | 1.86±0.18 | 1.13 | 0.67–1.55 | 5.54 | 4.18– 8.61 | 1.43 | −319.7 |
| V-71 | 386 | 116 | 0.052±0.019 | 1.58±0.24 | 2.88 | 2.20–4.03 | 18.7 | 10.7–50.2 | 0.10 | −226.7 |
| V-76 | 450 | 28 | 0±0 | 1.29±0.15 | 2.26 | 1.09–15.6 | 22.2 | 5.89–22500 | 3.82 | −246.5 |
| **F. Resmethrin** | | | | | | | | | | |
| O | 459 | 50 | 0.031±0.021 | 2.42±0.21 | 0.26 | 0.16–0.38 | 0.88 | 0.58– 1.82 | 1.89 | −171.0 |
| C | 255 | 30 | 0±0 | 2.60±0.35 | 0.41 | 0.29–0.55 | 1.29 | 0.86– 3.61 | 1.25 | −145.3 |
| V | 379 | 40 | 0±0 | 2.55±0.28 | 0.69 | 0.60–0.78 | 2.18 | 1.73– 3.04 | 0.26 | −214.0 |
| L | 219 | 359 | 0.020±0.007 | 2.92±0.40 | 1.62 | 0.89–2.34 | 4.46 | 2.91–19.36 | 1.10 | −148.9 |

[a]For abbreviations of column headings, see footnote *a* in Table I.
[b]C = *conflictana*; F = *fumiferana*; L = *lambertiana ponderosana*; O = *occidentalis*; V = *viridis*. Numerals after V indicate year of test.
[c]No confidence limits computed because g ≥ 0.50 at 95% level.
[d]No $LD_{50}$ or $LD_{90}$ values or their respective confidence limits computed because g ≥ 0.50 at 90% level.

were tested with the synthetic pyrethroids bioethanomethrin, + *cis* phenothrin, and resmethrin. *C. occidentalis* was the most susceptible to each, *lambertiana ponderosana* the least susceptible. The hypothesis of equality was rejected for these compounds, but parallelism was accepted for bioethanomethrin and resmethrin (Table V). When the halogenated pyrethroids permethrin and NRDC 161 were tested on *C. occidentalis* and *C. viridis* (Table IV), *C. occidentalis* was the most susceptible to each. The responses of the two species to either compound were not equal, but were parallel in the case of permethrin.

The unequal responses to insecticides shown by the *Choristoneura* species discussed in this study could significantly and adversely affect the results of control operations using extrapolation from one species of known response to a species of unknown response. This study, coupled with the extensive investigation of the shifting responses of *C. occidentalis* over time (Savin *et al.*, in press), demonstrates the need for carefully conducted research into the response of *Choristoneura* species before insecticides are applied against them in control operations.

Table V. Tests for equality and parallelism of response of *Choristoneura* species to insecticides

| Compound | Species[a] | Parallelism[b] | | | Equality | | |
|---|---|---|---|---|---|---|---|
| | | D.F. | $-2 \log \lambda$ | *p* | D.F. | $-2 \log \lambda$ | *p* |
| **A. Carbamates** | | | | | | | |
| Aminocarb | O,V | 1 | 0.59 | 0.444* | 2 | 107.50 | 0.000 |
| Carbaryl | C,O,L,V | 3 | 10.20 | 0.017 | 6 | 409.26 | 0.000 |
| Methomyl | C,O,V,L | 3 | 16.11 | 0.001 | 6 | 64.31 | 0.000 |
| Mexacarbate | P,O,F,L, V-71, V-76, C | 6 | 32.91 | 0.000 | 12 | 365.43 | 0.000 |
| **B. Chlorinated hydrocarbon** | | | | | | | |
| DDT | O,P,C,V-71, V-76, F,L | 6 | 69.28 | 0.000 | 12 | 327.18 | 0.000 |
| **C. Organophosphorous compounds** | | | | | | | |
| Acephate | V,L,O,C | 3 | 12.14 | 0.007 | 6 | 57.76 | 0.000 |
| Chlorphoxim | O,V | 1 | 0.16 | 0.684* | 2 | 25.95 | 0.000 |
| Chlorpyrifos | O,C,L,V | 3 | 5.20 | 0.158* | 6 | 88.53 | 0.000 |
| Chlorpyrifos-methyl | L,O,C,V | 3 | 0.99 | 0.803* | 6 | 169.70 | 0.000 |
| Fenthion | O,V | 1 | 23.49 | 0.000 | 2 | 32.86 | 0.000 |
| Fenitrothion | L,O,V,C | 3 | 17.28 | 0.001 | 6 | 42.75 | 0.000 |
| Malathion | C,V,L,O | 3 | 11.05 | 0.011 | 6 | 75.39 | 0.000 |
| Phosmet | V,L,C,O | 3 | 12.78 | 0.005 | 6 | 249.42 | 0.000 |
| Phoxim | L,O,C,V | 3 | 17.57 | 0.001 | 6 | 82.16 | 0.000 |
| Tetrachlorvinfos | O,V,L | 2 | 9.30 | 0.009 | 4 | 17.32 | 0.002 |
| Trichlorfon | C,O,V,L | 3 | 17.38 | 0.001 | 6 | 50.25 | 0.000 |
| **D. Pyrethroids** | | | | | | | |
| Bioethanomethrin | O,C,V,L | 3 | 2.82 | 0.421* | 6 | 123.56 | 0.000 |
| NRDC 161 | O,V | 1 | 873.39 | 0.000 | 2 | 94.61 | 0.000 |
| Permethrin | O,V | 1 | 0.22 | 0.639* | 2 | 25.94 | 0.000 |
| Phenothrin | O,V,C,L | 3 | 10.71 | 0.013 | 6 | 48.52 | 0.000 |
| Pyrethrins | C,O,F,L, V-76, V-71 | 5 | 36.10 | 0.000 | 10 | 195.94 | 0.000 |
| Resmethrin | O,C,V,L | 3 | 1.27 | 0.736* | 6 | 178.10 | 0.000 |

[a]C = *conflictana*; F = *fumiferana*; L = *lambertiana ponderosana*; O = *occidentalis*; P = *pinus*; V = *viridis*. Numerals after V indicate year of test.
[b]In column headings, D.F. is degrees of freedom, $-2 \log \lambda$ is the maximum log-likelihood value.
*Indicates hypothesis accepted, with $p \geq 0.05$.

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