TOXICITY OF PYRETHROID AND ORGANOPHOSPHORUS ADULTICIDES TO FIVE SPECIES OF MOSQUITOES[1]

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ABSTRACT. Four pyrethroids and four organophosphates were tested as contact aerosols in a wind tunnel device against adult female *Aedes taeniorhynchus* (Wiedemann), *Aedes aegypti* (L.), *Culex pipiens quinquefasciatus* Say, *Anopheles quadrimaculatus* Say, and *Anopheles albimanus* Wiedemann. In general, the pyrethroids, *d-cis*-resmethrin, *d-trans*-resmethrin, Roussel Uclaf RU-11679 ((5-benzyl-3-furyl)methyl *trans*-(+)-3-(cyclopentylidenemethyl)-2,2-dimethylcyclopropanecarboxylate), and RU-12061 (1-methyl 3-(5-benzyl-3-furyl)methyl *trans*-(+)-3-carboxy-α,2,2-trimethylcyclopropaneacrylate), were 1 to 2 orders of magnitude more toxic to the mosquitoes than the organophosphates, chlorpyrifos, Cidial® (ethyl mercaptophenylacetate, *S*-ester with *O,O*-dimethyl phosphorodithioate), chlorpyrifos-methyl, and malathion. Notable exceptions to this high order of toxicity occurred because of apparent natural tolerance of *A. taeniorhynchus* and *C. p. quinquefasciatus* to the pyrethroids.

We have continued to test selected adulticides against four species of mosquitoes in addition to our standard test species, *Aedes taeniorhynchus* (Wiedemann). The present paper reports on the toxicity of four new pyrethroid compounds and four organophosphate compounds used as contact aerosols against adult mosquitoes in a wind tunnel.

METHODS AND MATERIALS. The species of mosquitoes tested in addition to the standard species were *Aedes aegypti* (L.), *Culex pipiens quinquefasciatus* Say, *Anopheles quadrimaculatus* Say, and *A. albimanus* Wiedemann. All mosquitoes were from our laboratory colonies.

The four pyrethroids evaluated were: *d-cis*-resmethrin and *d-trans*-resmethrin (the *cis*-(+) and *trans*-(+) isomers of (5-benzyl-3-furyl)methyl-2,2-dimethyl-3-(2-methylpropenyl) cyclopropanecarboxylate); Roussel Uclaf RU-11679 ((5-benzyl-3-furyl)methyl *trans*-(+)-3-(cyclopentylidenemethyl)-2,2-dimethylcyclopropanecarboxylate), and RU-12061 (1-methyl 3-(5-benzyl-3-furyl)methyl *trans*-(+)-3-carboxy-α-2,2-trimethylcyclopropaneacrylate). The four organophosphates evaluated were: chlorpyrifos; Cidial® (ethyl mercaptophenylacetate, *S*-ester with *O,O*-dimethyl phosphorodithioate); chlorpyrifos-methyl; and malathion. The pyrethroid compounds included both unsynergized and synergized formulations. The synergized formulations were obtained by adding piperonyl butoxide at a ratio of 1 part adulticide to 5 parts synergist (w/w).

All compounds were tested as contact sprays in a wind tunnel. The tunnel consisted of a cylindrical tube 6 in. (15.5 cm) in diameter through which a column of air was blown at a rate of 4 miles (6.4 km) per hour by a centrifugal blower. The rpm of the blower was controlled by a variable autotransformer. Adult female mosquitoes (25 per cage) were confined in cardboard exposure cages, 3⅜ in. x 2 in. high (8.6 cm x 5 cm), with screened (16 mesh galvanized wire) ends and placed in the center of the tube for the exposures. Then 0.1 ml of a solution of the adulticide in kerosene (wt. A.I./vol. diluent) was atomized at a pressure of 1.5 pounds per square in. (105 g/cm²) into the end of the tunnel nearest the blower. Thus, the mosquitoes were exposed momentarily to droplets that were blown through the cage. After exposure, mosquitoes were anesthetized with carbon dioxide, transferred to cardboard holding cages (3⅜ in. diam. x 2 in. high) with nylon screen tops, and furnished with a 10% sugar-water solution. Holding cages

[1] This paper reflects the results of research only. Mention of a pesticide or a commercial or proprietary product in this paper does not constitute a recommendation or an endorsement of this product by the USDA.

Table 1. Toxicity of aerosols of pyrethroid and organophosphate adulticides to caged female *Aedes taeniorhynchus* exposed in a wind tunnel.

Adulticide	24 hour LC_{50} (ppm)	95 percent confidence limits	24 hour LC_{90} (ppm)	95 percent confidence limits
Synergized RU-12061 [a]	10	(8.1–12)	28	(23–35)
Snyergized RU-11679 [a]	11	(8.5–13)	29	(24–36)
Synergized *d-cis*-resmethrin [a]	6.9	(4.4–9.2)	30	(23–41)
Synergized *d-trans*-resmethrin [a]	19	(16–22)	42	(36–52)
Cidial	49	(42–56)	93	(79–121)
RU-12061	35	(25–44)	108	(88–147)
Chlorpyrifos	61	(52–70)	139	(114–184)
d-cis-resmethrin	36	(27–45)	143	(112–208)
RU-11679	53	(29–72)	202	(144–379)
Chlorpyrifos-methyl	108	(87–132)	256	(198–384)
d-trans-resmethrin	73	(57–89)	346	(259–530)
Malathion	186	(164–209)	407	(350–497)

[a] Synergized at a ratio of 1 part pyrethroid to 5 parts piperonyl butoxide (w/w).

were placed in a room maintained at ~75° F (24° C) and ~50 percent relative humidity. Mosquitoes were observed for mortality 24 hours after exposure to adulticides. Specimens handled in the same manner but exposed only to deodorized kerosene showed no mortality except for *A. quadrimaculatus* and *A. albimanus* which had 14 and 13% mortality, respectively.

Each adulticide was tested initially at a concentration of 1000 ppm and then at successively lower concentrations (500, 250, 100, 50, etc.) until a range of discriminating concentrations was noted. Additional tests were then conducted with a minimum of 4 discriminating concentrations until 16–64 cages of mosquitoes (400–1600 specimens) had been exposed to each adulticide. These concentration-mortality data were analyzed on a Hewlett-Packard Model 9810A programmable calculator using a probit analysis program written according to the procedures given by Finney (1971).

RESULTS AND DISCUSSION. The 24-hour LC_{50}'s, LC_{90}'s and respective 95% confidence limits for the mosquito adulticides tested are given in Tables 1–5. The adulticides are ranked in order of decreasing

Table 2. Toxicity of aerosols of pyrethroid and organophosphate adulticides to caged female *Aedes aegypti* exposed in a wind tunnel.

Adulticide	24 hour LC_{50} (ppm)	95 percent confidence limits	24 hour LC_{90} (ppm)	95 percent confidence limits
Synergized *d-cis*-resmethrin [a]	2	(1.4–2.5)	3.9	(3.1–5.9)
d-cis-resmethrin	2.9	(1.5–3.8)	6.1	(4.6–12)
RU-11679	4	(3–4.8)	6.7	(5.4–11)
Synergized RU-11679 [a]	3.2	(2.2–4)	7.3	(5.7–12)
d-trans-resmethrin	5.5	(4.3–6.8)	10	(8–17)
Synergized *d-trans*-resmethrin [a]	4.5	(3.5–5.5)	12	(9.3–17)
Synergized RU-12061 [a]	8	(6.5–9.6)	17	(13–26)
RU-12061	15	(12–19)	27	(22–38)
Chlorpyrifos	65	(55–77)	120	(98–172)
Cidial	66	(55–79)	136	(108–200)
Chlorpyrifos-methyl	77	(64–91)	139	(113–210)
Malathion	130	(109–151)	288	(241–374)

[a] Synergized at a ratio of 1 part pyrethroid to 5 parts piperonyl butoxide (w/w).

Table 3. Toxicity of aerosols of pyrethroid and organophosphate adulticides to caged female *Culex pipiens quinquefasciatus* exposed in a wind tunnel.

Adulticide	24 hour LC_{50} (ppm)	95 percent confidence limits	24 hour LC_{90} (ppm)	95 percent confidence limits
Synergized RU-11679[a]	8.5	(5.6–11)	21	(16–36)
Synergized *d-cis*-resmethrin[a]	6.5	(2.9–9.4)	22	(16–45)
RU-11679	19	(13–24)	61	(48–91)
Synergized *d-trans*-resmethrin[a]	26	(21–31)	70	(56–99)
Chlorpyrifos	58	(50–69)	109	(89–154)
Chlorpyrifos-methyl	63	(51–75)	123	(99–194)
d-cis-resmethrin	35	(22–46)	124	(95–193)
Cidial	59	(49–71)	124	(99–183)
Synergized RU-12061[a]	71	(59–87)	154	(119–246)
d-trans-resmethrin	84	(58–109)	264	(191–483)
RU-12061	289	(225–352)	519	(413–855)
Malathion	297	(260–335)	549	(470–687)

[a] Synergized at a ratio of 1 part pyrethroid to 5 parts piperonyl butoxide (w/w).

toxicity (at the LC_{90}) to each species of mosquito.

As a group, the four synthetic pyrethroids (both unsynergized and synergized) were 1–2 orders of magnitude more toxic to the mosquitoes than the organophosphates. Synergized *d-cis*-resmethrin and RU-11679 were more toxic to mosquitoes than any adulticide our laboratory has ever tested and, furthermore, were 2.5–8.5 times more effective than synergized pyrethrins (LC_{90}'s reported previously by Mount and Pierce 1973).

Unfortunately, exceptions to the extremely high toxicity of these pyrethroids were obtained in tests with *A. taeniorhynchus* (Table 1) and *C. p. quinquefasciatus* (Table 3). Natural tolerance in these two species was suggested by LC_{90}'s that were an order of magnitude higher than LC_{90}'s obtained for *A. aegypti* and the two *Anopheles* species. This tolerance was further demonstrated by 3 to 8X potentiations of the pyrethroids with the addition of piperonyl butoxide synergist. We reported previously that *A. taeniorhynchus* was tolerant of resmethrin, pyrethrins, and tetramethrin when these pyrethroids were tested unsynergized (Mount and Pierce, 1973 and Mount et al., 1974). The varia-

Table 4. Toxicity of aerosols of pyrethroid and organophosphate adulticides to caged female *Anopheles quadrimaculatus* exposed in a wind tunnel.

Adulticide	24 hour LC_{50} (ppm)	95 percent confidence limits	24 hour LC_{90} (ppm)	95 percent confidence limits
Synergized RU-11679[a]	0.9	(0.6–1.1)	2.7	(2.1–3.9)
Synergized *d-cis*-resmethrin[a]	0.6	(0.3–0.8)	3.1	(2.2–5.6)
Synergized RU-12061[a]	1.3	(0.6–1.8)	4.8	(3.4–10)
RU-11679	1.4	(1–1.9)	4.8	(3.8–7.1)
d-cis-resmethrin	0.7	(0.2–1.2)	6.1	(4.1–14)
Synergized *d-trans*-resmethrin[a]	2.5	(1.4–3.3)	6.4	(4.9–11)
d-trans-resmethrin	2.3	(1.1–3.4)	12	(8.8–23)
RU-12061	3.2	(1.8–4.4)	15	(11–33)
Chlorpyrifos	81	(63–99)	151	(119–248)
Cidial	123	(101–152)	189	(153–301)
Malathion	156	(132–178)	287	(246–356)
Chlorpyrifos-methyl	170	(123–214)	380	(295–585)

[a] Synergized at a ratio of 1 part pyrethroid to 5 parts piperonyl butoxide (w/w).

Table 5. Toxicity of aerosols of pyrethroid and organophosphate adulticides to caged female *Anopheles albimanus* exposed in a wind tunnel.

Adulticide	24 hour LC_{50} (ppm)	95 percent confidence limits	24 hour LC_{90} (ppm)	95 percent confidence limits
Synergized *d-cis*-resmethrin [a]	0.5	(0.2–0.7)	1.5	(1–3.9)
Synergized RU-11679 [a]	0.5	(0.2–0.8)	1.6	(1.1–4.1)
d-cis-resmethrin	0.9	(0.2–1.3)	2.5	(1.7–6.2)
RU-11679	0.7	(0.1–1.3)	3.4	(2.1–11)
Synergized RU-12061 [a]	1	(0.3–1.5)	3.8	(2.4–10)
Synergized *d-trans*-resmethrin [a]	1.7	(0.3–2.6)	4.1	(2.8–19)
d-trans-resmethrin	1.8	(0.1–2.7)	4.4	(3.1–17)
RU-12061	2.3	(0.7–3.5)	8.2	(5.5–24)
Chlorpyrifos	52	(24–68)	109	(81–303)
Cidial	83	(56–112)	195	(138–456)
Malathion	121	(89–149)	266	(211–394)
Chlorpyrifos-methyl	103	(43–145)	294	(204–652)

[a] Synergized at a ratio of 1 part pyrethroid to 5 parts piperonyl butoxide (w/w).

tions we observed between synergized and unsynergized pyrethroids tested against *A. aegypti* (Table 2), *A. quadrimaculatus* (Table 4), and *A. albimanus* (Table 5) were usually slight and in all instances except one were not significant at the 95% level of probability. RU-12061 was potentiated 3X against *A. quadrimaculatus* with the addition of piperonyl butoxide.

Among the organophosphates, chlorpyrifos and Cidial were not significantly different in toxicity to any of the five species; and they were significantly more toxic than malathion to the *Aedes* and *Culex* species (2.3–4.7X at the LC_{90}). Chlorpyrifos-methyl was equal to malathion against *A. taeniorhynchus*, and the *Anopheles* species, but was significantly more toxic than malathion to *A. aegypti* and *C. p. quinquefasciatus* (2 and 4.5X, respectively, at the LC_{90}).

Literature Cited

Finney, D. J. 1971. Probit Analysis, 3rd edition. Cambridge University Press. 333 pp.

Mount, G. A. and N. W. Pierce. 1973. Toxicity of selected adulticides to six species of mosquitoes. Mosq. News 33(3):368–370.

Mount, G. A., K. F. Baldwin and N. W. Pierce. 1974. Synergism of pyrethroids used as adulticides against *Aedes taeniorhynchus* (Wiedemann). Mosq. News 34(3):301–302.