The SNAKE, Vol. 28, pp. 23–27, 1998

THE TOXICITY OF COMMERCIAL INSECTICIDE AEROSOL FORMULATIONS TO BROWN TREE SNAKES

Joe E. Brooks, Peter J. Savarie and Richard L. Bruggers

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Animal Damage Control, National Wildlife Research Center, Ft. Collins, Colorado, USA 80524–2719

Abstract: A study was conducted in which brown tree snakes (*Boiga irregularis*) were treated dermally with 10 commercially available insecticides containing natural pyrethrins or synthetic pyrethroids, sometimes in combination with other insecticides or synergists. Snakes received 2 seconds of spray delivered from the aerosol containers. The results indicated that some pyrethrins/pyrethroids formulations are dermally toxic to brown tree snakes and that a concentration-effect relationship existed for at least pyrethrins. Synergists appeared to enhance the activity of the compounds, and at least one carbamate insecticide (propoxur) in one of the commercial formulations was potentially toxic to brown tree snakes.

Key words: Toxicity, Aerosol Insecticides, Brown Tree Snakes, *Boiga irregularis*

The introduced brown tree snake has extirpated several species of indigenous birds on the island of Guam and is currently threatening several others (Savidge, 1987). The snakes are significant pests of agriculture, public health and safety (Fritts *et al.*, 1994), and the economy (Fritts, 1988). Since Guam is the focal point for air and sea cargo to many other parts of the Pacific and the continental United States, a high risk exists for these snakes being introduced into these areas via cargo shipments. Methods are needed for managing snake populations on Guam and reducing risks of their introduction to other areas. Toxicant development is considered a high priority, as toxicants could be used in an integrated program to control brown tree snakes.

There is evidence from Japanese studies using several venomous snakes (*Trimeresurus flavoviridis*, *Agkistrodon blomhoffii brevicaudus*, *Crotalus adamanteus*, and *Naja atra*) in Okinawa (Toriba *et al.*, 1992) and the Oshima lizard (*Eumeces oshimensis*) (Kihara and Yamashita, 1978) that some pyrethrins are dermally toxic to these species of reptiles. The snakes died in a few hours after dermal exposure. Since pyrethrin-containing insecticides are registered as aerosol sprays for general public use by the U.S. Environmental Protection Agency (EPA), we sought to determine the effectiveness of commercial sprays when applied dermally to brown tree snakes. We reasoned that such products, if effective in killing snakes, could have great potential for use as snake sprays and that the active ingredients might be developed as contact or oral toxicants for snake management programs. Commercially available products could be particularly useful for home owners and facilities managers, since snakes are regularly found in and around housing and other structures on Guam.

Materials and Methods

Brown tree snakes were live-trapped in habitats on the island of Guam during operational snake control programs by U.S. Department of Agriculture/Animal Damage Control personnel. The snakes were transferred from traps into either wire holding cages or cloth bags for transport to the holding facility located at Andersen Air Force Base (AAFB). Snakes were weighed in cloth bags before being individually caged in plastic boxes with airholes on the sides. Each snake was assigned a unique accession number. Each cage contained newspaper on the bottom and a double-walled plastic dish

*Use of trade names does not constitute endorsement by the US Government or the authors.

Table 1. Trade names* and ingredients of the aerosol sprays used on brown tree snakes.

Trade name	Ingregients	
Top Crest House & Garden Bug Killer EPA Reg. No. 334–381–6165	Resmethrin	0.20%
	D-trans Allethrin	0.15%
	Inert	99.65%
Raid Flying Insect Killer$_{\text{Formula 5}}$ EPA Reg. No. 4822–284	d-cis trans Allethrin	0.143%
	d-cis trans Phenothrin	0.143%
	Piperonyl butoxide	0.50%
	Inert	99.214%
Raid Wasp & Hornet Killer$_{\text{III}}$ EPA Reg. No. 4822–224	O-isopropoxyphenyl methylcarbamate	0.467%
	Tetramethrin	0.369%
	Inert (contains petroleum distillates)	99.156%
Raid House & Garden Bug Killer EPA Reg. No. 4822–38	Pyrethrins	0.25%
	Piperonyl butoxide	1.05%
	Inert	99.70%
Black Flag House & Garden Insect Killer EPA Reg. No. 475–214	Tetramethrin	0.20%
	d-cis trans Phenothrin	0.191%
	Inert	99.609%
Raid Ant & Roach Killer$_{6}$ EPA Reg. No. 4822–323	Permethrin	0.20%
	Pyrethrins	0.20%
	Piperonyl butoxide	0.50%
	Inert (contains petroleum distillates)	99.10%
Whitmire PT230 Tri-Die EPA Reg. No. 499–223	Pyrethrins	0.30%
	Piperonyl butoxide	3.0%
	Silica gel	4.0%
	Inert (contains petroleum distillates)	92.7%
Whitmire PT565 Pyretrin EPA Reg. No. 499–182	Pyrethrins	0.50%
	Piperonyl butoxide	1.00%
	n-Octyl bicycloheptene dicarboximide	1.00%
	Inert	97.50%
Whitmire Aero Cide PT3–6–10 Pyrethrum Insect Fogger EPA Reg. No. 499–221	Pyrethrins	1.00%
	Piperonyl butoxide	2.00%
	n-Octyl bicycloheptene dicarboximide	3.33%
	Refined petroleum oil	8.00%
	Inert	85.67%
Whitmire X clude Encapsulated Natural Pyrethrum PT1600A EPA Reg. No. 499–239	Pyrethrins	0.30%
	Piperonyl butoxide	2.20%
	n-Octyl bicycloheptene dicarboximide	0.336%
	Petroleum distillates	1.209%
	Inert	95.955%

*Use of trade names for identification of products is not an endorsement by the authors or the U.S. Department of Agriculture.

with a hole cut into the side; this served as a water container and shelter. Water and paper were changed weekly. After caging, snakes were quarantined for a minimum of 3 days and then examined for general health by a veterinarian.

Snakes were randomly allocated to treatment groups by their initial body weights. Snakes were weighed again at the time of treatment. Four snakes of either sex were individually sprayed for 2 seconds with an aerosol insecticide along their ventral surface from the neck to the vent. The snakes were physically restrained during the treatment. Control (untreated) snakes were handled in the same manner except that no

aerosol was applied. The amount sprayed onto the snakes was estimated by subtracting the weight of the container after spraying from its prespraying weight. Treatments of snakes were made over preweighed paper towels that were again weighed immediately after treatment. By subtracting the amount on the paper, we estimated the aerosol formulation applied to each snake. Since inert ingredients in the commercial formulations were typically in the range of about 85 to 99% by weight, the reported figures only index the toxicity of active ingredients in the formulations.

After treatment, snakes were returned to their cages and observed for 72 hr for signs of intoxication or mortality. All animals surviving at the end of 72 hr were euthanized with halothane and disposed of by deep burial in a sanitary landfill.

The specifications for the commercial aerosol insecticide products examined in this study are given in Table 1*. Since several products contained petroleum distillates, this material was tested for its dermal toxicity.

Results

The amount of spray delivered onto the bodies of the snakes varied from 1.3 to 4.4 g; when adjusted for body weight (BW), it ranged from 19.2 g/kg BW to 64.5 g/kg BW. In general, small snakes ($\leq$100 g, n=16) received larger doses (approximately 45 g/kg BW) than larger snakes ($\geq$100 g, n=24, averaging 23 g/kg BW). This difference in amount of spray received may account in part for the slightly higher mortality (11/16) in smaller snakes *vs.* larger (14/24) snakes. From these average amounts, the approximate amounts of active ingredients delivered to the snakes were estimated (Table 2). These calculations must be considered as rough estimates since the methods of measuring spray delivery were rather crude.

Aerosol spray formulations containing pyrethrins, alone or in combination with other materials, proved to be toxic to brown tree snakes, resulting in death of 25 of 40 snakes (Table 2). Poisoning symptoms were seen within 1 hr of spraying and included generalized muscular tremors, disorientation, and sometimes a moribund state in 2 to 3 hr. Death usually occurred overnight, although some snakes died within 3–4.5 hr.

An aerosol spray formulation containing 0.143% allethrin and 0.143% phenothrin killed 3 of 4 snakes in less than 24 hr. However, another formulation containing allethrin at 0.15% combined with resmethrin at 0.20% failed to kill any of the test snakes.

Because the Raid Wasp and Hornet Killer sprayed a liquid jet, the amounts on the snakes were not measured accurately since the liquid soaked not only the preweighed paper towels but also the table top. The sprayed amounts from the can averaged 22 g/spray, and we estimated that each snake received about 6 g/spray. This formulation, containing the carbamate insecticide (chemical name propoxur) along with tetramethrin, killed all four snakes within 4.5 hr. However, another formulation containing tetramethrin and phenothrin did not kill any snakes during the 72-hr observation period, which suggests that the toxic ingredient may be the propoxur.

It was obvious that the sprays killed by dermal absorption. Since petroleum distillates were common to several of the formulations, especially those that killed snakes, these materials were tested for dermal toxicity by applying between 2 and 3 ml by disposable syringe to the bodies of the snakes; none showed any signs of intoxication and none died.

Discussion and Conclusions

Aerosol insecticide formulations were generally effective in killing brown tree snakes when applied dermally at rates averaging 23 to 45 g/kg body weight (2 seconds of spray). The most effective aerosols contained the highest percentage of active ingredients (Raid Wasp & Hornet Killer and the two Whitmire insect foggers containing 0.5 to 1.0% pyrethrins). Two products (Top Crest House & Garden Bug Killer and Black Flag House & Garden Insect Killer), which did not kill any snakes, contained relatively low levels of pyrethrins and did not contain synergists, such as piperonyl butoxide. Other products were intermediate in observed toxicity. The products containing natural pyrethrins and allethrin generally were toxic, and some

Table 2. Mortality of brown tree snakes exposed to commercial aerosol insecticide sprays.

Insecticide trade name	Active ingredients (a.i.)	Estimated average amount of a.i. delivered (mg/kg BW)	Snake mortality (24 h)	Snake mortality (48 h)
Top Crest House & Garden Bug Killer	Resmethrin Allethrin	38 29	0/4	0/4
Raid Flying Insect Killer$_{\text{Formula 5}}$	Allethrin Phenothrin Piperonyl butoxide	63 63 220	3/4	3/4
Raid Wasp & Hornet Killer$_{\text{III}}$	Tetramethrin Propoxur	196 254	4/4	4/4
Raid House & Garden Bug Killer	Pyrethrins Piperonyl butoxide	50 210	1/4 (dead in 4.5 h)	1/4
Black Flag House & Garden Insect Killer	Tetramethrin Phenothrin	46 44	0/4	0/4
Raid Ant & Roach Killer$_{6}$	Permethrin Pyrethrins Piperonyl butoxide	40 40 100	2/4	2/4
Whitmire PT230 Tri-Die	Pyrethrins Silica gel Piperonyl butoxide	193 1930 2573	3/4	4/4
Whitmire PT565 Pyrethrin Insect	Pyrethrins Piperonyl butoxide *n*-Octyl bicycloheptene dicarboximide	270 540 540	4/4	4/4
Whitmire Aero-Cide PT3–6–10 Pyrethrum Insect Fogger	Pyrethrins Piperonyl butoxide *n*-Octyl bicycloheptene dicarboximide Refined petroleum oil	320 640 1066 2560	4/4 (dead in 4.5 h)	4/4
Whitmire X-Clude Encapsulated Natural Pyrethum PT1600A	Pyrethrins Piperonyl butoxide *n*-Octyl bicycloheptene dicarboximide Petroleum distillates	102 748 114 412	3/4	3/4
Stoddard Solvent	Petroleum distillates	2–3 mL/snake	0/4	0/4
Untreated Reference		—	0/4	0/4

other ingredients (piperonyl butoxide and propoxur) were associated with snake mortality. Petroleum distillates were nontoxic to snakes when applied dermally in amounts of 2–3 ml per snake.

This study indicated that (1) some pyrethrins or pyrethroids are toxic when applied dermally to brown tree snakes, (2) there was a concentration/toxicity relationship for at least some materials, (3) pyrethrin synergists appeared to enhance the activity of these compounds for snakes, and (4) at least one carbamate insecticide (propoxur) is potentially toxic to brown tree snakes. Carbamate insecticide actions are often enhanced by their formulation with pyrethrins/pyrethriods or piperonyl butoxide (Doull *et al.*, 1975), which may provide an avenue for additional work.

Pyrethrins and some pyrethroids are photo-labile, that is, they rapidly degrade in the presence of sunlight into less active and possfbly less toxic substances (Otieno and Pattenden, 1980; Leahey, 1985). These and

other considerations will need to be addressed in developing toxicant delivery systems.

Acknowledgements.—We thank Edward Schafer and Michael Fall for review of the manuscript. We sincerely appreciate the help extended us in Guam by Michael Pitzler, Daniel Rodriquez and other staff of the USDA/ADC operations program for supplying the snakes used in the study. This study was conducted with funds provided to the U.S. Department of Agriculture/Animal and Plant Health Inspection Service/Animal Damage Control/Denver Wildlife Research Center by the U.S. Air Force under Legacy Project No. 1281, "Development of Chemical Control Methods for Brown Tree Snake Management."

References

Doull, J., C. D. Klaasen and M. O. Amdur, eds. (1975) Casarett and Doull's Toxicology: The Basic Science of Poisons. Second Ed. New York, Macmillan Publ. Co.

Fritts, T. H. (1988) The brown tree snake, *Boiga irregularis*, a threat to Pacific islands. U. S. Fish Wildl. Serv. Biol. Rep. 88. Washington, D.C. 36 pp.

Fritts, T. H., M. J. McCoid and R. L. Haddock (1994) Circumstances associated with bites of the brown tree snake (*Boiga irregularis*) on Guam. J. Herpetol., 28(1): 27–33.

Kihara, H. and H. Yamashita (1978) The lethal effects of pesticides on reptiles. The Snake, 10: 10–15, 93–94. [In Japanese with English summary]

Leahey, J. P. (1985) Metabolism and environmental degradation. Pages 263–342 *In*: J. P. Leahey, ed. The Pyrethroid Insecticides. Taylor and Francis, London.

Otieno, D. A. and G. Pattenden (1980) Degradation of the natural pyrethroids. Pestic. Sci., 11: 270–278.

Savidge, J. A. (1987) Extinction of an island avifauna by an introduced snake. Ecology, 68: 660–668.

Toriba, M., S. Senbo and Y. Kosuge (1992) New method and materials to prevent venomous snakes. The Snake 24(1): 114.

要　約

市販のエアゾール殺虫剤の成分のミナミオオガシラに対する毒性

Joe E. Brooks, Peter J. Savarie
and Richard L. Bruggers

天然ピレスリン，合成ピレスロイド，その他の殺虫成分や共力剤などを含む，市販されている10種の殺虫剤を，ミナミオオガシラの皮膚にかけたときの効果を検討した．ヘビはエアゾールの噴射を2秒間受けた．その結果，いくつかのピレスリン・ピレスロイドの組み合わせはミナミオオガシラに対して経皮的に毒性を持つことがわかった．そして少なくともピレスリンでは効果は濃度に関係がある．共力剤は殺虫成分の効果を高め，1つに含まれるカルバミル酸塩（propoxur）はそれ自身が毒性を持っている．

米国国立野生生物研究センター