RESIDUAL ACTIVITY OF PERMETHRIN ON CATTLE AS DETERMINED BY MOSQUITO BIOASSAYS[1]

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ABSTRACT. The residual effectiveness against laboratory-reared female *Anopheles quadrimaculatus* mosquitoes of a synthetic pyrethroid (permethrin) applied to cattle was determined. Twenty-four-hour postexposure mortality and the degree of successful blood engorgement were determined by exposing mosquitoes for 10 min to cattle. Three replicated assays were conducted and mortality determined at 1, 2, 5, 7, 14 and 21 days after each treatment with an oil-based formulation of permethrin (DeLice) or with an emulsifiable concentrate (Atroban) applied at label rates. Mosquito mortality ranged from 79 to 85% (1 day postapplication) to 12–38% (21 days postapplication).

INTRODUCTION

Mosquito populations are routinely combatted by adulticidal applications of insecticides around urban population centers. Such procedures, although effectively reducing the frequency of biting attacks on humans, fail to provide lasting protection from continuously developing mosquito populations. Some species of mosquitoes aggregate near cattle herds. Proposed integrated management strategies against the dark rice field mosquito, *Psorophora columbiae* (Dyar and Knab), have included the suggestion that cattle and other large domestic animals could be used as the focal point of adulticidal actions because this species prefers large animals as its primary host (Kuntz et al. 1982). Because *Ps. columbiae* requires 2–3 blood meals to become fully fecund (Horsfall 1942), residual treatment of host animals might furnish an opportunity to kill the mosquitoes prior to oviposition. On the basis of a computer-assisted simulation model of the riceland agroecosystem and *Ps. columbiae*, Focks and McLaughlin (1988) also suggest the potential of host management for *Ps. columbiae* population reduction. Although several approaches may be possible, the most readily achievable one, especially for initial testing of the concept, is the use of a toxic residual chemical insecticide application to the hosts.

The only chemical adulticide with relatively long persistence that has a label for use on cattle in the USA is the synthetic pyrethroid, permethrin. The residual activity of permethrin against the horn fly, *Haematobia irritans* (Linn.), has been documented by Kinzer et al. (1983). Byford et al. (1987) reported alteration of horn fly distribution on cattle treated with pyrethroid-impregnated ear tags. Schreck et al. (1984) demonstrated that mosquito bites were significantly reduced when permethrin was used to impregnate clothing worn by humans. C. E. Schreck (unpublished data) also observed knockdown levels of 60% or better of *Anopheles quadrimaculatus* Say mosquitoes exposed to cattle treated with permethrin during the cool season of the year. We conducted a field test to: 1) determine the duration of residual activity of permethrin on cattle by bioassay with caged *An. quadrimaculatus* adults and 2) compare activity levels of 2 permethrin formulations at 2 locations on the cattle.

MATERIALS AND METHODS

The test was conducted in Alachua County, Florida, from July 22 to September 16, 1987, on 6 cattle that ranged in an open pasture with a shallow water pond and contiguous scrub oak woodlands. The herd consisted of one Hereford bull, an Angus-Hereford cow and calf, an Angus cow and 2 Holstein cows. Two animals were used as controls and 2 for each treatment. Treatments consisted of an emulsifiable concentrate (EC) whole-animal spray and an oil-based pour-on formulation (OIL). Each animal received the same treatment for the entire test series. Replicated applications were made on July 22, August 5 and August 26, 1987.

The EC formulation (Atroban® 11.0%, 55%/45% *cis/trans*, Coopers Animal Health, Inc., Kansas City, KS) was diluted 1:200 (1 pint of Atroban in 25 gal water) and sprayed on the entire animal until runoff. The oil-based OIL formulation (DeLice® 1.09%, 35%/65% *cis/trans*, Coopers Animal Health, Inc., Kansas City, KS) was applied to the spine from the shoulders to the tailhead at the labeled amounts according to weight of the animals. Although these slight differences in the *cis/trans* rates

[1] Mention of a commercial or proprietary product in this paper does not constitute an endorsement of this product by the United States Department of Agriculture.

could conceivably be responsible for differing mortality, the objective of the test was to assess commercially available and labeled products for usage.

The bioassay consisted of exposure of unfed, 2- to 5-day-old laboratory-reared female *An. quadrimaculatus* mosquitoes to the top, sides and underside areas of cattle. When not on the cattle, the mosquitoes were restrained in cages (2.5 × 3.5 × 15.0 cm) screened on the top and with 4 large holes cut in the plastic on the bottom, which were covered with a solid movable strip of plastic. Four cages of ca. 20 females each were placed on each animal, 2 near the back line on the upper curvature areas and 2 along the bottom of the stomach area for 10 min. The cattle were restrained in a squeeze-chute and fed during the mosquito exposure period.

After assay on the cattle, cages were returned to the laboratory in the coolers, maintained at 21°C and covered with moist cloth. Cotton soaked in a honey water solution was placed on the cages until mortality rates were recorded 24 hr after exposure. The feeding rates of mosquitoes in each cage were also determined. The probability of contamination of the cages was reduced by the following precautions. Latex gloves worn by the attendants were removed and new gloves used between handling of each of the 3 types of treated cattle. The cages exposed to untreated animals were transported in a separate insulated chest. Those cages exposed to the insecticide-treated cattle were kept in separated areas of the same chest during transportation. Both insulated chests were lined with a clean plastic liner for each bioassay and contained frozen packets. Check cages of mosquitoes (2 for each cooler) were transported to the field and handled the same as the others, except that they were taken from the chests and exposed to ambient conditions but not to the cattle. Other cages with mosquitoes remained at the laboratory and served as checks of the effect of transportation and handling.

RESULTS AND DISCUSSION

Mortality among Nonexposed Checks: The laboratory control cage mortality averaged 0.07 ± 2.6% (range 0.0–11.7%, n = 30), indicating that caging of the females and holding in the laboratory, knockdown with CO_2 or their prior rearing conditions were not harmful. The cages taken to the field in the container with those cages to be used for bioassay on untreated cattle averaged 1.4 ± 3.9% (range 0.0–13.6%, n = 15), indicating that transportation in that container and the 10 min exposure to ambient conditions were not harmful. The cages taken to the field in the container used to transport the cages assayed on the insecticide-treated cattle averaged 8.3 ± 25.8% (range 0–100%, n = 15).

Mortality among Cattle-exposed Mosquitoes: Exposure of mosquitoes to untreated cattle resulted in greater mortality than would have been expected from the mortality of mosquitoes in unexposed field check cages. The increased death occurred among those females that did not feed. Although added stress of exposure to the hair and possibly elevated temperatures is a possible explanation, transfer of the chemical from the treated cattle to untreated cattle is more probable.

Exposure of mosquitoes to permethrin-treated cattle resulted in initial mortality of 79–85%, which declined to 51–65% at 7 days postapplication and 12–38% by 14 and 21 days postapplication (see Table 1). These data are in agreement with those of J. K. Olson who reported 1-day postapplication mortality of 77–94%, 6-day postapplication mortality of 51–89% and 0–3% mortality at 14 days postapplication (unpublished data). Comparison of mortality of fed and unfed mosquitoes from either permethrin formulation does not show the differences associated with engorged females that occurred on the untreated cattle. This tends to support the possibility that some degree of contamination of untreated animals from contact with treated animals did occur.

Mortality in Relation to Location on the Animal: Differences in response between the 2 formulations bear upon decisions for their use in a field control program. There were no differences ($P > 0.05$) in mortality between locations on the untreated animals. The average percentage mortality of mosquitoes among cages exposed to the upper or lower bottom areas of animals treated with insecticide is shown for each assay time posttreatment in Fig. 1. There were no consistent differences in mortality due to location in tests of cattle treated with the EC formulation. However, the OIL formulation was more potent on the upper than on the lower areas of the cattle during the 1st week postapplication; visual observations confirmed a progressively downward migration of the formulation as evidenced by adherence of dirt and a generally oily sheen to the hair. Data from assays of the OIL at 2 and at 3 weeks showed that mortality was greater on the lower parts of the animals than on the upper parts. The greater mortality at 3 weeks as opposed to that at 2 weeks reflects migration of the formulation to the underside areas of the animals where cages were placed. The oil line was between the top and bottom assay areas at 14 days.

Effect upon Percentage of Engorged Mosquitoes: Permethrin has been reported to be a con-

Table 1. Mean percentage mortality (± SE) of *Anopheles quadrimaculatus* female mosquitoes exposed to cattle treated with permethrin. Data are the average percentage mortality of 3 replicates, 4 cages per animal, 2 animals per treatment, with an average of 20 mosquitoes per cage, for assays conducted at the indicated number of days postapplication.

Days postapplication	Mosquito condition	Percent mortality ± SE		
		Untreated	Pour-on	Spray
1	Fed	8.3 ± 3.3	50.3 ± 10.5	65.8 ± 8.9
	Unfed	21.4 ± 5.4	84.6 ± 7.1	78.3 ± 5.1
	Mean	10.2 ± 2.8	84.6 ± 6.1	77.3 ± 4.6
2	Fed	6.4 ± 5.1	33.4 ± 10.9	75.1 ± 9.0
	Unfed	19.0 ± 6.4	93.6 ± 3.7	83.7 ± 5.7
	Mean	9.3 ± 2.6	84.5 ± 6.0	85.7 ± 4.9
5	Fed	1.8 ± 1.2	49.3 ± 12.1	71.7 ± 7.5
	Unfed	23.4 ± 7.7	86.6 ± 6.3	84.0 ± 6.0
	Mean	9.1 ± 2.8	72.8 ± 7.8	77.9 ± 6.1
7	Fed	5.8 ± 2.5	60.8 ± 8.7	47.9 ± 8.3
	Unfed	26.5 ± 6.1	62.5 ± 8.9	53.2 ± 9.3
	Mean	15.2 ± 3.2	62.7 ± 8.5	50.9 ± 8.2
14	Fed	0.6 ± 0.6	9.3 ± 4.5	10.6 ± 4.7
	Unfed	13.4 ± 4.6	38.0 ± 8.1	40.2 ± 7.0
	Mean	6.5 ± 2.2	20.4 ± 5.7	22.2 ± 5.1
21	Fed	0.0 ± 0.0	22.2 ± 9.3	1.4 ± 1.0
	Unfed	2.4 ± 1.1	52.2 ± 10.8	31.9 ± 8.6
	Mean	1.9 ± 0.9	38.5 ± 9.3	12.1 ± 2.9

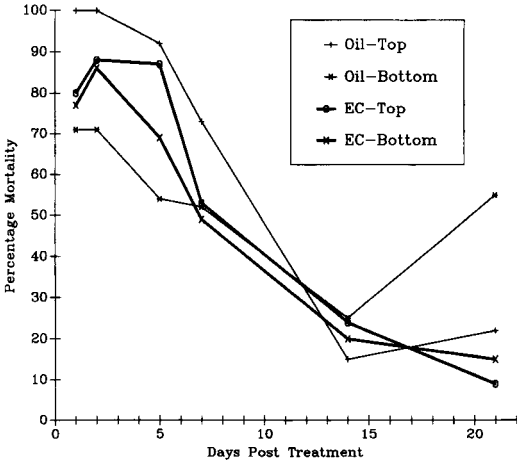

Fig. 1. Mean percentage mortality among female *Anopheles quadrimaculatus* mosquitoes in cages exposed to the upper or lower areas of cattle treated with permethrin (Atroban emulsifiable concentrate or DeLice oil-based formulations) for assays up to 21 days postapplication.

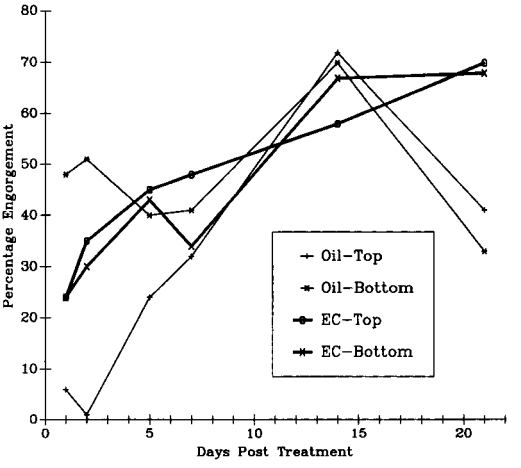

Fig. 2. Mean percentage engorgement among female *Anopheles quadrimaculatus* mosquitoes in cages exposed to the upper or lower areas of cattle treated with permethrin (Atroban emulsifiable concentrate or DeLice oil-based formulations).

tact toxicant that causes rapid irritation to insects and subsequent flight away from the surface (Khan and Colwell 1984, Shemanchuk 1981 and C. E. Schreck, personal communication). In our tests, the mosquitoes attempted to feed but quickly returned to the walls of the cages after tarsal contact with hair. The degree of this reaction varied with time postapplication, location on the animals and formulation. The mortality data in Table 1 show that unfed mosquitoes experienced greater mortality than those that stayed on the animal and became engorged. Figure 2 shows the percentages of mosquitoes that fed according to formulation and cage location. The movement of the OIL from the upper to the lower areas of the animals is indicated by the decrease in the degree of feeding during the first 5 days posttreatment by mosquitoes exposed on lower areas of the cattle. Engorgement percentages were equal to those for mosquitoes exposed

to untreated cattle. However, mosquitoes placed on the upper parts of the animals during the first 2 days made brief contact with the hair and promptly returned to the cage, often dying before cages were removed from the animal. On the 5th day postapplication, about 20% feeding occurred as compared to 40–50% in the other treatment groups. In spite of the rapid disengagement reaction, sufficient material existed on the hair to kill the mosquitoes after only brief contact.

CONCLUSIONS

Both formulations of permethrin were highly effective against the mosquitoes during the 1st week after application. However, the effectiveness of both formulations decreased to levels below 50% mortality after the first week. The OIL formulation applied to the back-line of the animals was more effective on the top of the animal than the EC formulation but less effective on the bottom except at 21 days, when the material had accumulated on the bottom line of the cattle.

Our observations suggest that *An. quadrimaculatus* females sense permethrin through tarsal contact receptors and not by chemoreception of air-borne vapors. The mosquitoes would always leave the sides of the cages and land, although briefly, upon the cattle hair; during the earlier periods postapplication, avoidance then occurred by a rapid retreat to the cage walls, often followed by "knockdown" before the end of the exposure time. Later, when the amount of permethrin had decreased to levels that presumably did not irritate the tarsal receptors, feeding occurred but mortality also occurred. No data were gathered regarding the probable effects of sublethal doses upon oviposition, longevity or fecundity of *An. quadrimaculatus* females.

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