J. Med. Entomol. Vol. 23, no. 4: 396-399 July 1986

PRESSURIZED SPRAYS OF PERMETHRIN OR DEET ON MILITARY CLOTHING FOR PERSONAL PROTECTION AGAINST *IXODES DAMMINI* (ACARI: IXODIDAE)[1,2]

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Abstract. Pressurized sprays of commercially available permethrin at 0.5% or deet at 20 or 30% concentrations applied to military field uniforms were evaluated as protectants against *Ixodes dammini* at Great Island, West Yarmouth, Massachusetts, USA, during May 1984. The tick-infested test site was in southeastern Massachusetts, where Lyme disease and babesiosis are zoonotic. A 1-min application of permethrin to the exterior surface of pants and jackets provided 100% protection against attack by all life stages of the tick, while 1-min applications of 20 and 30% deet provided 86 and 92% protection, respectively. These differences were statistically significant ($P \leq 0.05$) for adult ticks and for all tick life stages considered together.

A deer tick, *Ixodes dammini* Spielman, Clifford, Piesman & Corwin, 1979, is considered the principal vector of Lyme disease (LD) and human babesiosis in the northeastern United States. Lyme disease is a tick-borne spirochetosis of humans (Burgdorfer & Keirans 1983) with symptoms often resembling arthritis; in some cases it manifests more severe complications. Babesiosis is a malarialike disease caused by the sporozoan parasite *Babesia microti* (Dammin et al. 1981; Spielman et al. 1985).

Based on recent reports (Anon. 1984, 1985) and personal communication with Dr Lori Markowitz of the U.S. Public Health Service, Center for Disease Control, Atlanta, GA, it appears that LD may be more frequently transmitted than other tick-borne diseases and may well exceed the others in numbers of cases in the United States.

Victims of LD are most often people who have frequented the habitat of *I. dammini*, a 3-host tick that parasitizes birds and mammals. All life stages, including larvae and nymphs, attack man. The vector tick develops over a 2-year period: adults quest during fall and during occasional warm spells in winter, larvae during the following summer, and nymphs during spring and early summer 1 year later. Adults feed mainly on deer, while immatures feed on the White-Footed Mouse, *Peromyscus leucopus*. These mice are the presumed reservoir hosts for both infections (Spielman et al. 1985).

Until more is known about the epidemiology of LD and babesiosis and the control of *I. dammini*, effective personal protection chemicals are needed for people most often exposed in endemic areas. One chemical to consider is deet (*N,N*-diethyl-*meta*-toluamide), an EPA-labeled repellent commercially available and widely used against mosquitoes, biting flies, chigger mites, and ticks. A 2nd chemical, permethrin, is also labeled by EPA and is commercially available, but mostly in southern states. It is a synthetic pyrethroid for use on clothing only and has been reported to be effective both as an impregnant and as a pressurized spray against 4 species of ticks of medical and veterinary importance, namely, *Amblyomma americanum* (L.) (Schreck et al. 1982; Mount & Snoddy 1983), *Dermacenter variabilis* (Say) (Mount & Snoddy 1983), *D. occidentalis* Marx, and *Ornithodoros coriaceus* Koch (Lane & Anderson 1984). Permethrin has not been tested against *I. dammini*.

Reported here are tests comparing a pressurized spray of permethrin with 2 commercially available spray formulations of deet as clothing treatments to protect people exposed to *I. dammini* in regions where LD and babesiosis are endemic.

MATERIALS AND METHODS

The study was performed on Great Island, a forested peninsula in West Yarmouth, Massachusetts, USA. This site, on the south shore of Cape Cod, is visited during the summer by about 200 people. Of these, about 10% have been infected by the

1. This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by the U.S. Department of Agriculture nor does it imply registration under FIFRA as amended.

2. Research reported here was conducted in part with contract funds from the U.S. Army Medical Research and Development Command, Ft. Detrick, Maryland, and grants from NIH, the National Institute of Allergy and Infectious Disease, and from David Arnold.

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Lyme disease spirochete and about 1% by *Babesia microti* (Schreck, unpubl. data). Work was done during May 1984, a season when all life stages of *I. dammini* seek hosts. The resident deer herd had been removed from the site during the previous several months, a factor that may have contributed to the numbers of questing ticks observed during the study. Mean temperature and relative humidity recorded during the tests were 16 °C (10–19 °C) and 67% (40–92%). *Ixodes dammini* adults and nymphs were active even at the lowest temperatures recorded.

The clothing tested (trousers and jacket) was the U.S. military battle dress uniform (BDU) made from 50% nylon and 50% cotton twill and printed with a 4-color camouflage pattern. The source of permethrin was Permanone Tick Repellent (0.5% AI), a pressurized spray manufactured by Fairfield American Corp., Newark, NJ. The sources of deet were 2 commercially available pressurized sprays containing 20 and 30% deet in their respective formulations.

Three sets of BDU clothing were issued to each of the test volunteers. Each set was marked to indicate its designated treatment. Thus separate clothing was used for each treatment and the control; clothing was not exchanged among individuals.

To simulate actual use, subjects sprayed their own assigned sets of clothing as uniformly as possible (spray nozzle held ca. 30 cm from the cloth) at a nearby field laboratory in a space protected from wind and immediately before wear in each test. Jacket and trousers were hung or laid down and were sprayed on both sides for a total of 30 s for each garment. The previously untreated clothing was prewashed in a commercial laundry with detergent and then rewashed after each test.

Persistence of sprayed-on permethrin was not studied in these investigations because of logistical considerations and because complete protection for 3 successive daily exposures with the same spray treatments against *A. americanum* was reported by Schreck et al. (1982). To avoid contamination among treatments, the subjects wore shorts or bathing suits during the treatment procedures, and clothing subjected to different treatments was washed separately and stored in individual plastic bags.

Owing to the risk of tick-borne disease, care was taken to protect test individuals against tick attachments. The cuffs of the trousers were either taped or tucked carefully inside footwear to prevent ticks from penetrating to the inside of the trouser legs. Ticks found attempting to attach to the skin during the field exposure period were removed and recorded. None attached successfully.

A balanced block design was used for the tests. Each block consisted of 6 individuals (5 men and 1 woman) in 3 paired treatments. Treatments were deet (product A and product B, one on each of 2 individuals), permethrin on each of 2 individuals, and 2 untreated controls. Three blocks/day were conducted when possible in an arrangement similar to that described by Mount & Snoddy (1983). Each treatment was paired on 2 individuals, and they wore a different treatment for each block at different times during each day of tests. Thus 12 blocks were completed in 5 days of testing (2 on 1 day and 1 on another), giving 12 paired replications/treatment.

Each block consisted of a 1-h field exposure, during which the individuals randomly and intermittently walked, stood, sat, or lay in tick-infested habitat while ticks were permitted to crawl on the clothing. The 6 persons with their respective treated clothing circulated through a new 0.8–1.6-ha (2–4-acre) test plot each time for the first 7 replicates, then returned and repeated tests in some of the same plots for the remaining 5 replicates. During these 1-h exposures, *I. dammini* ticks were collected from heavy white cotton flannel drags (0.5 m wide × 1.5 m long), which were pulled along the ground or over low vegetation.

The drags were used to locate areas of greatest tick activity and to determine proportions of life stages. Numbers and life stages of ticks found on the drags were recorded; these ticks were then placed on either treated or untreated clothing for subsequent observation.

After each field exposure the test group returned to the field laboratory where the clothing was removed and examined for ticks. Ticks present on the body and clothing were removed, counted, and recorded as to species, life stage, sex, mortality, and whether attachment had occurred.

Experimental results from each pair of similarly treated individuals were summarized for evaluation using analysis of variance (ANOVA) at the 0.05 level of significance. A log transformation [$\log(x + 1)$] was used in the analysis because of unequal variances with the untransformed tick-count data.

During and after each test, samples of ticks on treated and untreated clothing were removed and placed in vials for observation for up to 24 h to

TABLE 1. Personal protection from attack of *Ixodes dammini* with pressurized sprays of permethrin or deet applied to outer clothing, Great Island, Hyannis, Massachusetts, May 1984. (Means of twelve 1-h test exposures.)

Life stage and adult sex	0.5% permethrin		Deet formulations				Untreated
			Product A (20%)		Product B (30%)		
	Mean no. live ticks/person	% protection	Mean no. live ticks/person	% protection	Mean no. live ticks/person	% protection	Mean no. live ticks/person
Larvae	0 a*	100	0 a	100	0 a	100	0.67 a
Nymphs	0 a	100	0.25 b	83	0 a	100	1.5 b
Adult ♀♀	0 a	100	0.67 b	87	0.5 b	90	5.08 c
Adult ♂♂	0 a	100	0.83 b	85	0.58 b	90	5.5 c
All ticks	0 a	100	1.75 b	86	1.08 b	92	12.75 c

* Mean numbers of live ticks in the same row not followed by the same letter are significantly different at the 0.05 level.

determine if mortality occurred as a result of these various exposures.

RESULTS

Permethrin provided complete (100%) protection to individuals from attack by all life stages of *I. dammini* (Table 1), while spray formulations of deet (product A, 20%, and product B, 30%) provided 86 and 92% protection, respectively. These differences were statistically significant for adult ticks and for all tick life stages considered together. No differences for larval ticks could be determined because the numbers were too small: larvae constituted only 4% of all life stages found on clothing. For nymphal ticks, which made up 11% of such collections, the deet products differed from each other as well as from permethrin. The greater concentration (product B at 30%) provided 100% protection, while the lesser (product A at 20%) provided 83% protection from nymphs.

Adults constituted 85 and 82% of *I. dammini* found on clothing and on drags, respectively, while sexes were found in equal proportions on both.

Exposure to tick attack for each treatment during the tests was probably about equal, based on the numbers of ticks recorded from the drags. The average number of ticks/test collected by the subjects wearing deet, permethrin, or untreated control clothing was 16.6, 17.1, and 17.6, respectively.

A total of 1,431 *I. dammini* (233 nymphs) was counted on clothing or on drags during the tests; however, many more ticks were observed in the leaf litter. Thus the human subjects were exposed to a much greater population of *I. dammini* than is indicated in Table 1, which reflects only the numbers of live ticks on clothing after 1 h of exposure.

Most ticks placed on the clothing from drag collections did not remain there long, owing to the repellency of deet or the lethal effect of permethrin. Further, it was observed that even on the untreated fabric, all life stages of *I. dammini* had some difficulty in clinging to the relatively smooth, closely woven fabric. When test subjects were immobile, lying, or sitting in tick-infested "hot spots," those ticks that attempted to crawl onto clothing were either repelled by the deet or knocked down by the permethrin treatment, but on the untreated control they continued to crawl about. However, when the control subjects moved, many of the ticks were brushed off by the dense vegetation or fell because they were not firmly attached to the fabric.

The American dog tick, *D. variabilis*, was not the subject of this study; however, it was recorded on clothing and/or drags in every test. Although the numbers were too small for statistical analysis, an average of 2.3 American dog ticks/test was found on the untreated control and 0.17/test on clothing treated with deet product A. None were found on the permethrin or deet product B treatments.

We observed that all life stages of *I. dammini* and adult *D. variabilis* lost control of normal movement and eventually died after contact with permethrin-treated clothing for 15 s or more. No mortality was observed among ticks exposed to the deet treatments.

DISCUSSION

These findings generally agree with the earlier investigations of Schreck et al. (1982), Mount & Snoddy (1983), and Lane & Anderson (1984), in which permethrin appeared to provide excellent protection against a number of medically important tick species.

Ixodes dammini seemed markedly less aggressive and was more easily brushed from the clothing than *A. americanum*, a species observed in similar studies elsewhere (Schreck et al. 1982). These tendencies may have contributed to the relatively low

numbers of ticks found on subjects wearing the untreated BDU in this study. Ticks appeared to cling to the coarse fabric of the drags better than to the smooth, close weave of the military clothing. Thus the type of fabric in clothing may considerably influence the number of *I. dammini* that can remain on a human host long enough to find a feeding site. The BDUs themselves would tend to protect the wearer against *I. dammini.*

Based on these studies and others mentioned in this report, several points should be considered when attempting to protect against attack by *I. dammini.* We think that the taping of pants cuffs or placing them inside of footwear increases personal protection against *I. dammini.* This procedure prevents the movement of ticks from leaf litter and higher vegetation to untreated legs and the inside of pants. Thus the pant cuff protection method should be employed by persons frequently exposed to populations of *I. dammini* and other species of ticks.

The advantage of a toxicant (permethrin) over a repellent (deet) when used for protection against vector species of ticks is evident from these tests. Permethrin offers the potential for 100% protection because exposed ticks are killed, while deet apparently does not provide complete protection nor does it kill ticks. Our data suggest that doses of deet higher than those used in the present test may provide higher levels of protection (>92%); however, this would have to be shown by additional experimentation.

Acknowledgments. We thank Steven Bloemer, Kenneth Posey, Cindy Russell, and Daniel Smith for their technical assistance. Special thanks are expressed to Victor Chew, USDA Mathematical Statistician, for his assistance in designing the tests and to Rulon Wilcox and the Chase family for permitting access to the test area.

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