PERMETHRIN-TREATED JACKETS VERSUS REPELLENT-TREATED JACKETS AND HOODS FOR PERSONAL PROTECTION AGAINST BLACK FLIES AND MOSQUITOES

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ABSTRACT. The concept of using wide-mesh jackets treated with a synthetic pyrethroid rather than a conventional vapour repellent for protection against biting flies is examined. This principle, previously studied by the USDA Insects Affecting Man And Animals Research Laboratory at Gainesville, Florida, is based on the hypothesis that the toxic action of the treatment would quickly affect biting behavior as well as reduce insect populations in the vicinity of subjects wearing jackets to levels where effective personal protection is provided.

Jackets treated with (a) 3-phenoxybenzyl(±) *cis,trans*-2,2-dimethyl-3-(dichlorovinyl) cyclopropane carboxylate (permethrin), (b) the standard repellent N,N-diethyl-m-toluamide (deet) and (c) the experimental repellent tetrahydrofurfuryl octanoate were compared for their efficacy against black flies and mosquitoes in a series of field tests at Canadian Forces Base (CFB) Petawawa in Ontario. The ability of repellent-treated hoods to provide protection for the wearer's face was also investigated.

The jackets treated with permethrin provided subjects with good protection against black flies and mosquitoes but, based on averaged landing counts, were not as effective as jackets treated with deet, especially for protecting the face during initial exposure to the insects. The toxic action of permethrin-treated jackets reduced the black fly and mosquito population in a given area to much lower levels after approximately 10 min exposure after which effective protection was afforded.

Hoods treated with deet were as effective as jackets treated with deet or with tetrahydrofurfuryl octanoate in providing protection for the face. Against the black fly and mosquito species active during testing, tetrahydrofurfuryl octanoate was found to be as effective as deet when used as a jacket treatment.

INTRODUCTION

Extensive testing in several countries under a variety of conditions has established that repellent-treated, wide-mesh jackets provide effective personal protection against biting flies (Gorham 1974, Grothaus et al. 1975, Lindsay 1975, Sholdt et al. 1975, McAndless and Underwood 1976, Grothaus et al. 1976). These garments, originally developed by the USDA Insects Affecting Man and Animals Research Laboratory (IAMARL), Gainesville, Florida, and the US Navy Medical Field Research Laboratory (NMFRL), Camp Lejeune, N.C. are constructed from lightweight netting made of polyester filaments for strength and of cotton strands to absorb the repellent (Grothaus et al. 1975). The jackets are waist length with a hood for covering the head but not the face (Figure 1).

Usually the jackets are impregnated with a "space repellent," a chemical which affects biting insects in the vapor phase although direct contact with the treated surface by insects can also produce repellent action. The repellent most often used is N,N-diethyl-m-toluamide (deet), although several other compounds have been investigated as jacket treatments (Gorham 1974, Sholdt et al. 1975, McAndless and Underwood 1976). When treated with an effective repellent, the jackets may provide protection against mosquitoes, black flies and some other arthropod pests for several weeks depending upon the activities of the wearer and other variables (Grothaus et al. 1975, 1976). Disadvantages of the treated jackets include a flammability hazard (Lindsay 1975) and a restriction on the mobility of the wearer due to snagging when moving through brush.

Recently, field tests conducted by IAMARL indicated that jackets treated

with resmethrin, a synthetic pyrethroid insecticide, provided personnel with protection against a deer fly and *Ae. taeniorhynchus* (Schreck et al. 1977). The effect of the jacket treatment was to reduce the number of attacking insects in a given area to low levels. In these tests there was little evidence of repellency, the protection perhaps resulted from contact of the insects with the pyrethroid. Several potential advantages of using this kind of toxicant as a jacket treatment instead of a repellent were revealed by these field tests. For example, killing the insects may offer a means of providing "area" protection for a group of individuals, some of whom may not be wearing protective jackets, as opposed to the action of repellents which generally have little or no effect on a given insect population other than providing the wearer with temporary relief from bites. The pyrethroid treatment is almost odorless and is not oily, thus having a greater acceptance value.

Consequently, it was decided to investigate further the use of toxicant-treated jackets as a means of protecting personnel against biting flies, particularly against some of the species of black flies and mosquitoes found in Canada. Specifically, we were interested in comparing the efficacy of jackets treated with the synthetic pyrethroid permethrin (3 - phenoxybenzyl(±)-*cis-trans*-2,2-dimethyl-3-(dichlorovinyl) cyclopropane carboxylate) and jackets treated with the standard repellent N,N-diethyl-m-toluamide (deet). Of the synthetic pyrethroids available, permethrin was chosen as a jacket treatment since this compound combines the desirable features of high potency at low concentration against many insect species, as well as good photostability and extremely low mammalian toxicity (Elliot 1976, Bader 1976).

Tests on the permethrin-treated jackets were carried out at Canadian Forces Base (CFB) Petawawa in Ontario as part of a field trial to compare the efficacy of jackets treated with deet and the promising experimental repellent tetrahydrofurfuryl octanoate (THFO). In addition, an evaluation was carried out to determine whether a repellent-treated hood constructed of the wide-mesh material could provide as much facial protection as a complete jacket ensemble. In the military context, the use of a hood alone offered several advantages over the jacket ensemble, such as economy, reduction in snagging when moving through dense brush, less bulk and weight, less repellent required, reduction in the flammability hazard and ease of storage.

MATERIALS AND METHODS

JACKETS AND HOODS. Jackets (Figure I) were constructed according to the NMFRL design using S–1624 jacket netting, Polylox Corp, New York, N.Y. Some of these jackets were treated at the rate of 0.25 g per gram of netting by immersing the garments in isopropanol solutions of deet or THFO repellent while others were treated at the rate of 0.07 g per gram of netting by immersion in an acetone solution of permethrin.

Hoods (Figure 2) were constructed from the netting using the same design as those hoods which were an integral part of the jacket ensemble. In addition, a neck flap approximately 8 cm wide was sewn around the lower portion of the hood and all edges of the netting were trimmed with a close-weave nylon strip. The hoods were treated with deet at the same rate as the jackets.

Following treatment, the jackets and hoods were air dried overnight to permit evaporation of the solvent and each item was then stored in a foil-lined paper bag until used. Several untreated jackets, complete with hoods, were worn as control items during the field evaluations.

FIELD TESTS. The treated jackets and hoods were evaluated at CFB Petawawa during the last week in May and first week in June, 1977. Test sites selected at different locations on the base were heavily wooded and located near a lake, stream or swampy area. All sites were infested with mixed populations of black

Fig. 1. Subject Wearing Insect-Repellent Jacket.

flies and mosquitoes with the former predominating. The following species were representative of the biting flies collected during testing: *Simulium venustum* (Say) and *S. decorum* (Wlk) (black flies); *Coquillettidia perturbans* (Wlk), *Aedes vexans* (Mg), *Ae. cinereus* (Mg), *Ae. intrudens* (Dyar), *Ae. sticticus* (Mg) and *Ae. stimulans* (Wlk) (mosquitoes).

Six men were used as subjects throughout the field trials. Tests were usually carried out during the morning or evening when the insects were most active. For each test, jackets were worn over dark green coveralls with the hood over the head and with the sleeves covering the arms to the wrist. In evaluating the jackets, the number of insect landings which

Fig. 2. Subject Wearing Repellent-Treated Hood.

occurred on the face was considered indicative of the relative effectiveness of individual items; data for landings which occurred on the hands or on the front of the jackets are included for reference purposes. Subjects wearing permethrin-treated jackets were located at least 50 m from control subjects wearing untreated jackets so as to avoid the possibility of control landing counts being affected by the treatment's action. When separate hoods were undergoing tests, they were worn in the same configuration as the hoods of the jacket ensembles. In these tests, the hands of subjects were left unprotected to give an indication of whether any protection for the hands was being offered by the hoods.

A typical routine for each test was as follows:

i) Subjects were transported to a test site and issued appropriate experimental items;

ii) Those subjects wearing items with identical treatments sat in prearranged pairs for 10 min, and each subject recorded the number of insect landings which occurred on the face and hands of his partner using 2 hand-held counters (Figure 3). A landing was defined as one in which an insect alighted and began to probe or bite. When testing permethrin-treated jackets, landing counts were taken on the face and front portion of the jacket from neck to waist but excluding the sleeves;

iii) Tests proceeded for a period (e.g. 1 hr) sufficient to accumulate a relatively large number of control and test landing counts. Control subjects then donned test items while other subjects removed their test items, changed into clean overalls and donned untreated jackets. Following this exchange, landing counts were taken for another period. Care was taken to ensure that each test item and subject was exposed to the biting-fly population for the same length of time;

iv) Procedure (iii) was repeated at least 3 times so that at the conclusion of the evaluation, each subject had tested each type of available test item at least once and had a acted as a control several times;

v) During each test, dry-bulb temperatures, relative humidity and wind speeds were recorded. Representative insect specimens which landed on subjects were collected using an aspirator for species identification later.

vi) At the conclusion of testing all equipment was collected and the subjects were transported from the site.

DATA ANALYSIS. Since each treated jacket, hood, untreated control jacket and subject was exposed to the insect popula-

Fig. 3. Subjects Recording Insect Landings.

tion for the same length of time. (*viz*: 1 hr) data from the tests could be combined and averaged in terms of landing counts per subject for a given item. An "efficacy rating" was calculated for each item using the formula:

$$\text{Efficacy Rating} = [(N_c - N_i)/N_c] \times 100$$

where N_c = average landing count per control subject,

and

N_i = average landing count per subject wearing a treated item.

The calculated efficacy ratings were usually based on data from three repeat tests carried out at each of 3 different sites to give a total of 9 replications.

In the case of permethrin-treated jackets, landing counts per subject were also averaged over each 10 min segment from the start of a given test to determine whether the toxic action of the treatment was affecting the rate at which landings were occurring.

RESULTS AND DISCUSSION

COMPARISON OF PERMETHRIN- AND DEET-TREATED JACKETS. Using averaged data, the results shown in Table I indicate that deet-treated jackets are more effective than permethrin-treated jackets in protecting personnel against the test species of mosquitoes and black flies. The difference in protection afforded to the face by the 2 types of jackets was significant (5% significance level) using a chi-square analysis method (Fisher 1945).

It was noted that a large proportion of landing counts for those subjects wearing permethrin-treated jackets occurred during the first 10 minutes of each test. As illustrated in Figure 4 using data from a separate test where landing counts on the fronts of control jackets and permethrin-treated jackets were monitored, the average landing count for a subject wearing a permethrin-treated jacket decreased rapidly following the first 10 to 20 min of exposure. Much lower count rates were observed for the remainder of the test. Once a degree of "area" control of the insect population had been achieved (10 to 20 mins following initial exposure), the permethrin-treated jackets seemed to protect the wearer's face and body effectively, especially where 2 or more individuals wearing the garments were located close together.

As indicated in Figure 4, some variability in the count rate occurred during this single test, particularly for the control count rate. However, the trend in count rates shown by the data for subjects wearing the permethrin-treated jackets was consistent with observations made during other tests involving these test items.

The area over which a jacket treated with permethrin was effective was not determined during testing. It was noted that unprotected individuals not involved in the testing, e.g., vehicle drivers, commented on several occasions that they were no longer being bothered by biting flies when they stood within a few feet of a subject wearing a treated jacket. In addition, testing was not of sufficient duration to determine whether the treated jackets were losing their effectiveness during the time of exposure.

Several advantages of permethrin-treated jackets over repellent-treated jackets became apparent during the evaluations. Aside from the possibility that a few individuals wearing the

Table 1. Protection provided by permethrin- and deet-treated jackets against black flies and mosquitoes

Jacket Treatment	Average Landing Counts Per Subject			Efficacy Rating	
	Face	Jacket Front	Total	Face	Total
Deet	13	35	48	91	83
Permethrin	32	46	78	78	73
None (Control)	137	152	289	0	0

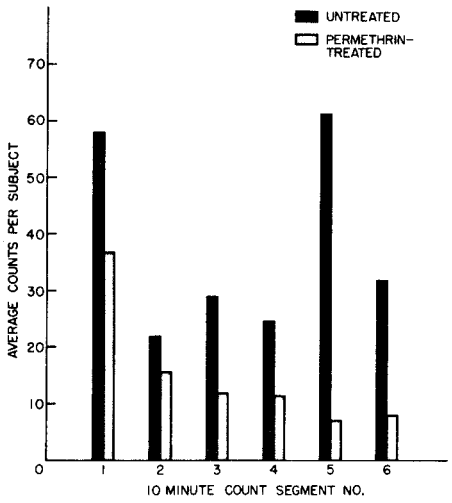

Fig. 4. Landing Counts on Front of Jackets for Consecutive 10 Minute Periods.

pyrethroid-treated jackets in a given location might provide "area" protection for other personnel, the relatively small amount of chemical used in the jacket produced little distinctive odor and left the jacket material with a natural, non-greasy feel. This is particularly significant from the military point of view where individuals on sentry duty or reconnaissance require protection from insect pests and must avoid detection by enemy forces.

Wearing repellent-treated jackets can prevent bites occurring on surfaces covered by the fabric and on the bare face when the hood is in place. However, biting flies may continue to land and probe all surfaces not treated with repellent (e.g. trouser legs). In fact, even though biting may be prevented by the repellent-treated jackets, the continual presence of a cloud of insects around an individual can be an annoyance which restricts the person's productivity (Gorham 1974). The ability of pyrethroid-treated jackets to reduce the number of blood-feeding insects in a given area (Schreck et al. 1977) offers a means of alleviating this annoyance problem, especially where attacking insects are numerous.

In mobile situations, repellent-treated jackets would be expected to be more effective than those treated with pyrethroid because of the latter's apparent delayed action against the pest insects. This problem of delayed action might be overcome, for example, by using a more potent pyrethroid (e.g. decamethrin) or by the use of synergists with the pyrethroid treatment to shorten insect knockdown and kill times. Further work is necessary to establish whether these approaches can improve the initial protection provided by pyrethroid-treated jackets.

COMPARATIVE TESTS OF REPELLENT-TREATED JACKETS AND HOODS. Jackets treated with either deet or tetrahydrofurfuryl octanoate (THFO) and hoods treated with deet were compared for their efficacy against the black fly and mosquito populations found at CFB Petawawa. Using the described efficacy rating, the results shown in Table 2 indicated that all items tested were effective in protecting the face and, with respect to the treated jackets, the hands were protected to a large extent as well. The deet-treated hood by itself provided little protection for the hands. A chi-square analysis of the data in Table 2 indicated

Table 2. Protection provided by repellent-treated items against black flies and mosquitoes

Item	Treatment	Average Landing Counts Per Subject			Efficacy Rating	
		Face	Hands	Total	Face	Hands
Jacket	THFO	13	67	80	92	83
Hood	Deet	17	398	415	90	1
Jacket	Deet	24	104	128	85	74
Jacket	none	164	403	567	0	0

no significant difference (P = 0.05) in the level of protection provided to the face by the two treated jackets and the hood.

In situations where an individual's clothing provides adequate biting-fly protection for the body, wearing a repellent-treated hood and applying repellent to the hands appear to be practical alternatives to wearing a repellent-treated jacket. This is especially true for those individuals who don't mind applying liquid repellent to the hands every few hours but are averse to applying it to the face. The possibility of contamination of the eyes by repellent is also reduced. As indicated, using a hood alone for protecting the face offers several advantages over the jacket ensemble such as increasing the mobility of the wearer by less snagging, reducing the amount of weight and volume carried, lowering the overall cost of the protective garment and reducing the flammability hazard.

Under the given conditions, the results indicate that tetrahydrofurfuryl octanoate (THFO) as a jacket treatment is as effective as deet in protecting personnel against the species of black flies and mosquitoes encountered.

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