INSECT REPELLENT JACKET: STATUS, VALUE AND POTENTIAL[1]

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ABSTRACT. Lightweight net jackets were treated with N, N-diethyl-*meta*-toluamide at the rate of ⅛, ¼, and ½ gm per gm of netting. Field studies indicated that the ¼-gm treatment level would provide protection from mosquitoes for 6 weeks. The jackets provided protection against *Culicoides furens* (Poey) for over 7 weeks at the ¼-gm treatment level. Studies with deer flies proved more variable. One jacket provided 91% protection after 2 weeks at the ½-gm treatment level while another failed. Through the work of several investigators, a relatively complete picture of the effectiveness of the insect repellent jacket now exists. It has been tested in a variety of countries and climates. On the basis of the data now available, we feel that the deet-treated jacket will provide protection against a variety of blood-feeding dipteran species for at least 6 weeks.

INTRODUCTION

With the realization that many of the present insect control techniques were going to be restricted or eliminated prior to development of acceptable alternate control schemes, many workers in the vector control field became concerned about the lack of effective personal protection systems. In 1965 the Naval Medical Field Research Laboratory (NMFRL) team began placing priority on developing protective devices designed to provide a high degree of consumer acceptability along with acceptable mosquito protection. In cooperation with the Insects Affecting Man Research Laboratory, USDA, we developed an extensive research program on space repellents and their application to the protection of civilian and military personnel in areas where older disease-vector control techniques were prohibitive or impractical. Early work included the treatment of wide-mesh netting with repellents known to provide spatial action (Gouck et al. 1967a, 1967b; Schreck et al. 1970). This work resulted in improved bed nets, tent drops, and all-purpose netting (Grothaus and Adams 1972, Grothaus 1974; McDonald and Grothaus 1973).

During the same period of time, studies were initiated on net jackets (Grothaus and Adams 1972). Earlier work indicated the shirts (jackets) might prove to represent a breakthrough in providing acceptable personnel protection from disease vectors (Travis and Morton 1946; Cherepanov and Gomoiunova 1963). Continued studies by the USDA team confirmed this work. Coincidental to the USDA-NMFRL research, it was shown that repellent-treated jackets provided protection from mosquitoes and tabanids in the United States (Catts 1968). Studies by the U. S. Army showed that deet-treated jackets provide good blackfly protection with good consumer acceptability (Frommer et al. 1975, in press).

Canadian investigators tested the USDA-NMFRL jacket and found it was as effective as topically applied repellent and overcame some of the disadvantages of applying liquid repellent directly to the skin (McAndless 1974; Lindsay 1975). Promising results have also been achieved against the tsetse fly in Ethiopia (Sholdt et al. 1975). The most recent work shows the deet-treated jacket will provide about 2 weeks protection against the Valley

[1] The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large. Mention of a commercial or proprietary product does not constitute a recommendation or an endorsement of the product by the U. S. Department of Agriculture or the U. S. Navy.

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Black Gnat (*Leptoconops carteri*) before retreatment is necessary (Mulrennan et al. 1975).

MATERIALS AND METHODS

Although many repellents were tested during our previous wide-mesh netting research, studies on the net jacket at Camp Lejeune, N. C. were generally restricted to various strengths of deet (N, N-diethyl-*meta*-toluamide). During 1973–1975, deet-jacket combinations were tested at the ⅛, ¼, and ½ gm deet/gm netting levels by treating the fabricated jackets with appropriate amounts of deet-acetone solutions. The jackets were then allowed to air-dry. Following impregnation, the jackets were hung in an aging chamber at ambient temperature (70° F±5° F). The jackets were constructed from S-1624 netting.[4]

Field test procedures varied depending on the species of insect being challenged. When possible, the same test subjects were used when studying a given species. Normally, 2 to 3 subjects wore test jackets containing repellent while 1 subject wore an untreated jacket. One individual also served as a control, wearing only a white "T" shirt. Subjects testing jackets also wore "T" shirts. The same subjects were used in each study, so jackets were rotated during each test within the study. This procedure was used to allow for differences in the attractancy of the test subjects. The treated jackets were deemed to have failed if protection fell below 90% on 2 consecutive tests as compared to the control. Tests were conducted once a week until the jackets failed or the species in question failed to provide adequate biting pressure.

During studies with mosquitoes and *Culicoides* sp., the test subjects were taken to the field and positioned so that each could observe the other. Bite counts were conducted by counting and/or collecting all specimens biting above the waist. Depending on the test insect, standing or sitting positions were assumed during the test. The control subject was always placed 10–15 meters away from the other subjects to prevent competition between subjects. Tests with *Chrysops* sp. were conducted by having 2 subjects make a 1-mile walk together in a 30-minute period. Each subject aided the other in counting landings on the back and shoulders. It was found that insufficient biting pressure occurred when the subjects were not in motion. Because of the intense biting pressure, it was necessary to consider any landing as a potential bite. Although it was obvious that this technique would bias the data against the jacket, it was felt that this was the more proper procedure to avoid overly optimistic conclusions. When collecting during a test proved impractical, other techniques were used to establish data on biting populations present at the test site, and the test subjects recorded only the total bites or landings depending on the species under study.

During the *Chrysops* work, continuous collecting was accomplished by trapping. In addition, biting collections were made after the tests to aid in providing a complete list of the species present. During the *Culicoides* season, periodic biting collections were made.

DISCUSSION AND RESULTS

NETTING. Considerable effort was expended on testing different types of netting fabric for the jackets. The use of a netting type material was chosen to reduce body heat load in hot environments and improve consumer acceptance. Our first studies were conducted with a very strong ¼-inch mesh spun cotton-polyester fabric (Fig. 1). Both pullover and front opening jackets were constructed from this netting.

Our final prototype was designed as a waist-length overjacket with extra-length sleeves and a hood with drawstring designed to cover the head, but not the face.

[4] S-1624 jacket netting, available in 2,000-yd lots from Polylox Corp., 31 W. 54th St., New York, N. Y. 10018.

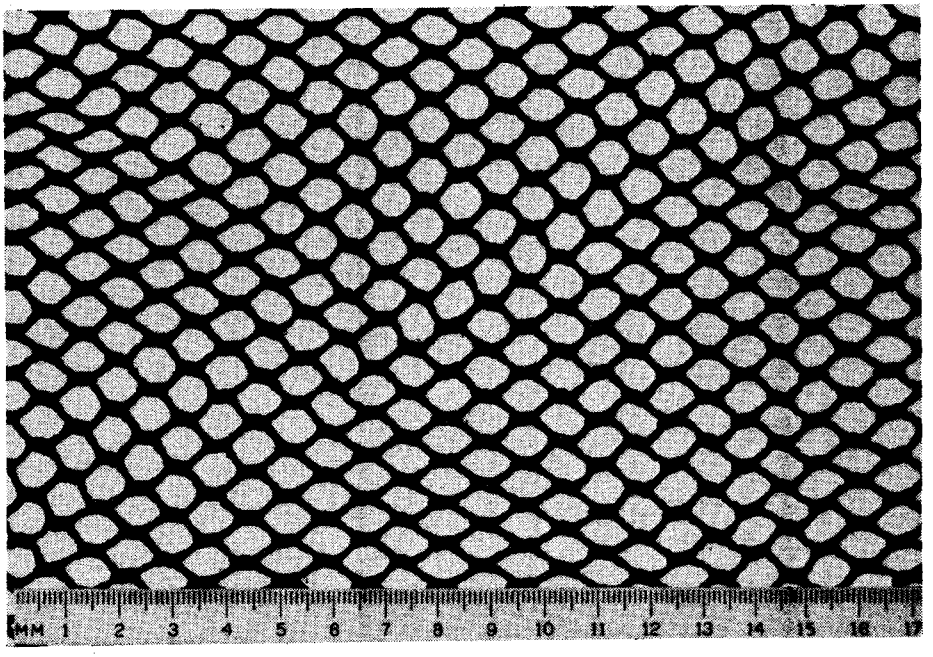

Fig. 1. Spun, cotton-polyester fabric, ¼-in. (0.635 mm) mesh.

The long sleeves were provided so the user could draw the hands inside the jacket if necessary (Fig. 2). The fabric used in the final prototype consisted of a lightweight polyester netting, S-1624, containing strands of cotton (Fig. 3). Some type of cotton combination was present in all of our test fabrics because we found it impossible to achieve the desired repellent treatment levels without the cotton to serve as a reservoir. Various techniques were tested in an attempt to impregnate lightweight synthetic fabrics. Repellents were applied directly to the fabric and also during the extrusion process of manufacturing. It was found that if the repellent was added to the liquid synthetic fabric precursor, it became bound and was not released to the environment. Direct application to the finished fabric either resulted in the destruction of the fabric or non-absorption of the chemical. The absorptive qualities of cotton were found to be ideal and necessary for use with spatial action repellents. Nylon "4" proved to be the only material with characteristics similar to cotton, but this material was experimental in nature and expensive to produce. It also began to deteriorate after prolonged exposure to repellents.

MOSQUITOES. Repellency studies against mosquitoes were conducted at ⅛, ¼, and ½ gm deet/gm netting fabric. Two ⅛-gm jacket test series were conducted during periods of high field mosquito incidence. The average bites per hour on the controls were 149 and 143, respectively. During the first study, the treated jackets (3) provided 100% protection for 9 weeks, when the mosquito population fell and the test was terminated. During the second study, the jackets failed to provide 90% protection at 8 weeks of aging. This indicated that the ⅛-gm treatment was more subject to erratic results than the higher dosages, possibly because of differing climatic and environmental factors. During subsequent years, we tested at the ¼- and ½-gm levels. The ¼-gm study continued for 14 weeks before protection

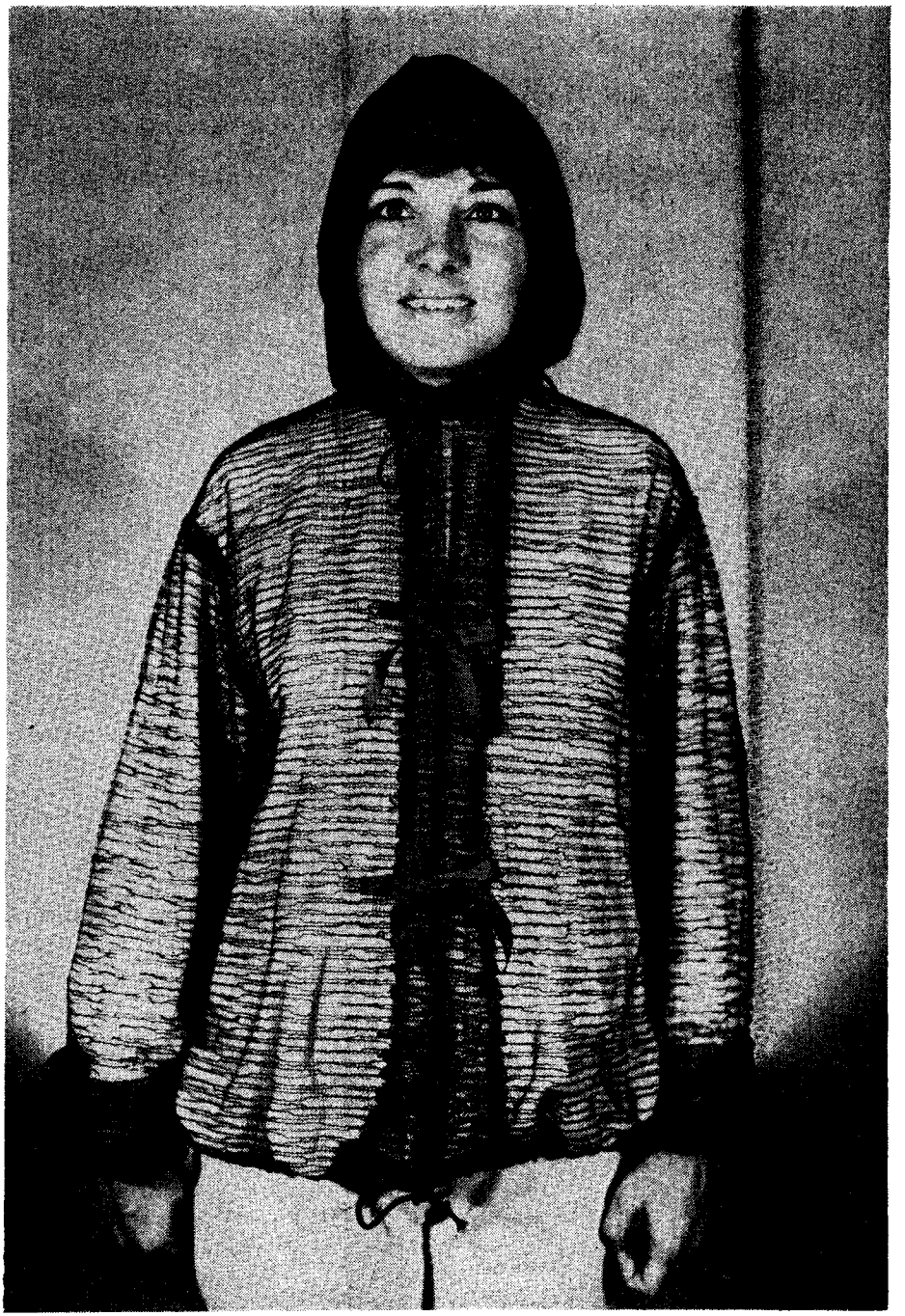

Fig. 2. Insect repellent jacket with open hood in place.

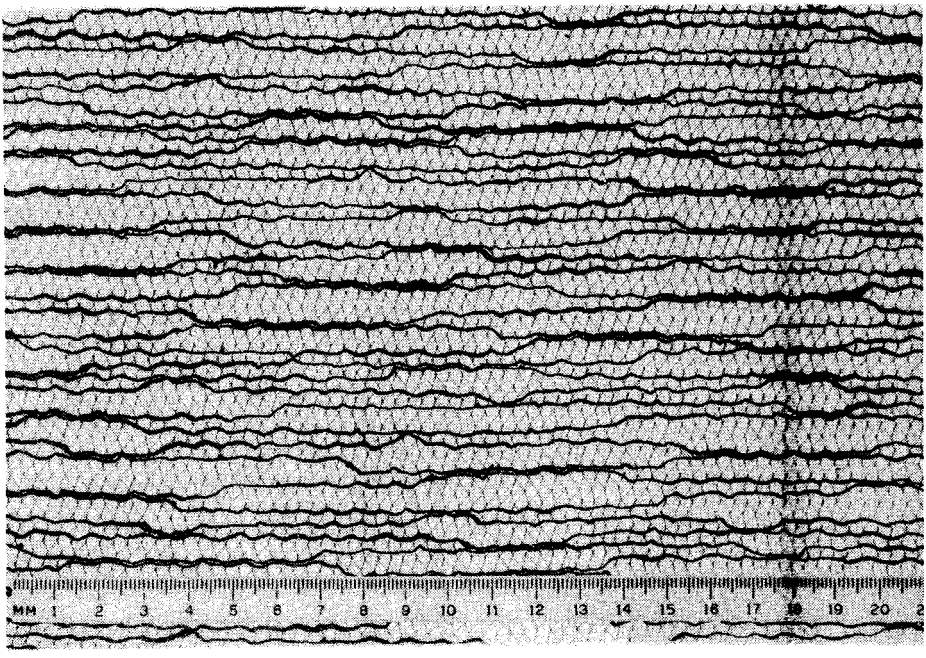

Fig. 3. Lightweight polyester netting with cotton strands running through it.

fell below 90%. The average protection prior to failure was 98% with an average bite pressure of 459/hr. The ½-gm treatment was conducted for 6 weeks and terminated after it was determined that the treatment was too high for good wearer comfort. It also seemed highly unlikely that the jackets would fail during a given mosquito season.

During this study the following species were collected:

Anopheles quadrimaculatus Say, *Psorophora ciliata* (Fabricius), *P. confinnis* (Lynch Arribálzaga), *P. ferox* (Humboldt), *Aedes atlanticus* Dyar and Knab, *Ae. dupreei* (Coquillett), *Ae. sollicitans* Walker), *Ae. taeniorhynchus* (Wiedemann), *Ae. triseriatus* (Say), *Ae. vexans* (Meigen), *Culex quinquefasciatus* Say.

During failures, no particular species was noted to be the first to attack the wearer of the treated jackets. Rather, collections from individuals wearing treated jackets were mixed. As the repellent vaporized to a level near the minimum effective dosage necessary to prevent biting, the first bites occurred on the exposed face. It would appear that as the vapor was reduced, the amount over the face fell below protection levels while the jacket area still contained sufficient chemical to prohibit landing and feeding.

Based on these studies, it was evident that practical levels of repellent should be in the ¼-½ gm/gm netting range, at least for mosquito protection. It was also noted that under moderate mosquito pressure, the use of the jacket gave 8–14 weeks protection. Previous studies on bednets had shown that deet-treated netting gave less than this period of protection. It would appear that the different type of netting and the use of the netting close to the body where body heat could provide more complete vaporization may have brought about increased protection time. In Alaska, under the pressure of large numbers of

pest mosquitoes, the jacket provided protection for less than 2 weeks (Gorham 1974), indicating that a relationship may exist between population pressure and protection time. This is not surprising since one might expect to find increased feeding response under these circumstances. However, considering the populations encountered by Gorham, it was encouraging to find that the jacket did provide protection (without a closed face hood). Considering the ease of retreating the jacket using a repellent aerosol can, etc., the jacket should give good protection against mosquitoes in north temperate regions of the world.

DEER FLIES. Our studies with deer flies were also conducted at 3 repellent treatment levels (⅛, ¼, ½ gm/gm netting). The ⅛-gm treatment provided only 80% protection during the first field test 1 week following treatment (3 jackets), when the pressure on the control consisted of only 40 landings per hour. The ¼ gm deet/gm net jacket treatments were aged for 1 month prior to the first test to reduce research time. The first test at this treatment level also resulted in complete failure of the jackets to protect and repel deer flies (control landings and bites/hr, 235). Final tests were conducted at ½-gm levels against heavy pressure (507 landings and bites/hr) and test results were mixed. After 2 weeks of aging, 1 jacket failed while 1 provided 91% protection against landings and bites. Single day "spot" tests revealed that freshly treated jackets would frequently fail to prevent landings and bites, particularly if the wearer actively moved through brushy woods containing high populations.

Attempts to collect biting specimens during a walking, timed test proved impossible so only the number of landings and bites were recorded during the actual tests. Collections made at the test site confirmed the presence of the following species: [5]

Chrysops brimleyi Hine, *C. callidus* Osten Sacken, *C. dimmocki* Hine, *C. flavidus* Wiedemann, *C. macquarti* Philip, *C. obsoletus* Wiedemann, *C. vittatus floridanus* Johnson.

Other tabanids present during the test were *Diachiorus ferrugatus* (Fabricius), *Tabanus americanus* Forster, and *T. lineola* Fabricius.[5] Although no specific studies were conducted on horse flies, it was observed that no bites occurred on wearers of the treated jackets during any of the various studies.

Culicoides sp. Although several species of *Culicoides* exist in the North Carolina coastal region, *Culicoides furens* (Poey) is the most consistent and vicious pest at Camp Lejeune. This species appears in the spring and fall during cool damp periods, reaching high population levels, but quickly disappears when conditions are not favorable. Nicknamed "flying teeth" by our field staff, *C. furens* was included in the field tests more because of availability than the belief that protection could be provided by the repellent-treated jacket. Again, tests were conducted at the ⅛ and ¼ gm deet/gm netting level with controls averaging 108 and 149 bites/hr, respectively (3 replications). The ⅛-gm test was terminated after 3 weeks and the ¼-gm test was concluded after 7 weeks. During the test periods, no specimens were observed biting an individual wearing a treated jacket. During other tests on other insects, massive 1-day populations of *Culicoides furens* were also observed to avoid completely anyone wearing the treated jackets, while unprotected personnel were actually driven from the test site. We feel these data are more than sufficient to show that the jackets are highly effective against this insect. Certainly at the ¼-gm treatment level, the jackets should provide in excess of 6 weeks protection against this species.

It can be seen that we now have a relatively complete picture of the effectiveness of the insect repellent jacket. It has been tested in a variety of countries and cli-

[5] Determinations by J. F. Burger, Smithsonian Institution, Washington, D. C.

mates against a variety of key insects. On the basis of the considerable data thus far accumulated, we feel that the deet-treated jacket will provide at least 6 weeks of protection against a variety of blood-feeding dipteran species.

We recognize that a problem exists with respect to repelling deer flies. Data from tests against these insects appear to be more variable, indicating rather poor protection values. However, preliminary studies with another repellent, 3-Acetyl-2-(dimethyl-5-heptenyl)-oxazolidine (AI 3-28963),[6] indicate that when treated with this material, the jacket may give better protection than deet, and if the need is sufficient, commercial development may be justified.

It is anticipated that insect repellent jackets will be available by early 1976 from at least 2 commercial sources.[7, 8] Thus, after several years of research, the practical application of spatial action repellents will become a reality. Hopefully, as new repellents become available, more thought will be given to the use of this protective concept. The concept of area repellents and repellents applied to structures is in its infancy; however, it may hold promise in vector-borne disease protection where residual pesticides have failed or have been restricted in their use. In the past, little attention has been given to the thought that repellents cause little or no major changes in ecosystems where they are present. With the present concern over the environment in which we live, a tool which is inherently safe by definition and has little impact on the environment should be viewed with considerable excitement.

[6] Experimental compound R69(R), provided by S. C. Johnson & Son, Inc., Racine, Wisc.

[7] Holubar Mountaineering Ltd., Boulder, Colo., member company of Johnson Diversified, Inc., 1525 Howe St., Racine, Wisc. 53403.

[8] Wildlife Development Federation of N.A., 1201 J St., Lincoln, Nebr. 68508.

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