Tropenmedizinisches Institut der Universität Tübingen, Medical Research Center, Kumba, Cameroon

Trials of garments impregnated with "Deet" repellent as an individual protection against *Simulium damnosum* s. l., the vector of onchocerciasis in the savanna and forest regions of Cameroon[1]

By A. Renz[2] and P. Enyong

Abstract

Garments, impregnated with Diethyl-toluamid ("Deet"), were tested in areas where onchocerciasis is hyperendemic against the vector flies, namely *Simulium squamosum* in the rain-forest and *S. damnosum* s. str./*S. sirbanum* in the Sudan savanna.

The wearing of garments (long trousers and jacket with hood, made of wide-mesh material), impregnated with 120 cc of "Deet", reduced the fly biting density by about 90 % during a period of 5–7 days (40–56 h of exposure) as compared to control subjects without such protective

[1] These investigations received financial support from the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases.
[2] Whilst working under a research grant from FAO/UNDP/World Bank/WHO Onchocerciasis Control Programme in the Volta River Basin.

Z. ang. Ent. 95 (1983), 92–102

ISSN 0044-2240 / InterCode: ZANEAE

garments, who were wearing only shorts and short-sleeved shirts. After that period, the degree of protection quickly fell to the level of an untreated garment, i.e. about a 47 % reduction in biting density. During these experiments, the garments were used for 8 h per day and kept closed in a plastic bag when not in use. Full-time exposure to the open air resulted in a quick drop of efficacy within three days in the savanna; but in the rain-forest full efficacy was maintained for 5 days, the longest period tested.

Less than 3 % of all flies biting a person without protective garments attacked the face and hands. The numbers biting these sites were not significantly increased by wearing untreated or treated protective garments. On a person without protective garments 24 % of all flies were caught on the uncovered feet below the ankles, but 45 % more flies were caught on these parts of the body when the legs were covered by an untreated protective garment. After impregnation of the garment, the number of flies coming to these uncovered parts of the body was reduced by 72 to 84 % during the first days of exposure as a result of the spatial action of the repellent.

1 Introduction

In the savanna and rain-forest regions of West Africa blackflies of the sibling species *Simulium damnosum* s. l.[3] are the vectors of *Onchocerca volvulus* and additionally, in some places, they constitute a severe biting nuisance. The prevention of their bites is the only personal protective measure available against the transmission of human onchocerciasis.

Diethyl-toluamide ("Deet") insect repellent, applied to the skin, has been found to prevent biting of *Simulium damnosum* in Ethiopia for a period of up to 10 h (SCHMIDT 1977). GROTHAUS et al. (1976) outlined the advantages of wide-mesh net clothing impregnated with "Deet", as compared to the topical application of this compound. Garments, made from such material, and consisting of a jacket with a hood, have already been successfully tested against palearctic Simuliids in Canada (LINDSAY and MCANDLESS 1978) and New York (FROMMER et al. 1975), and against tropical species in Costa Rica (SHIEFER et al. 1976). Although apparently less effective against Simuliids than against other blood-feeding Diptera, one impregnation of the garment was found to be effective for up to several weeks in temperate climates (GROTHAUS et al. 1976; FROMMER et al. 1975).

In the present study, the possibility of using "Deet"-impregnated garments was to be investigated in the different vectors of onchocerciasis in the rain-forest and savanna regions of West-Africa and with regard especially to the preference of *S. damnosum* for biting on the lowest parts of the body (DUKE and BEESLEY 1958).

The efficacy of a single application of "Deet" to the garment, and the period of protection so afforded, were to be examined under various conditions. In addition, observations were to be made on the physical wear of the garment tissue and the willingness of the local African populations to accept them.

2 Material and methods

Both in the rain-forest and the savanna, the experiments were carried out near breeding sites of *S. damnosum* at villages with hyperendemic onchocerciasis. The different clinical and ophthalmological manifestations of the rain-forest and savanna types of onchocerciasis and, in

[3] Where the name *Simulium damnosum* is used in this paper, it refers, unless otherwise indicated, to *S. damnosum* sensu lato; see VAJIME & DUNBAR (1975) for reclassification of the *S. damnosum* complex.

particular, the higher eye-pathogenity of the disease in the savanna, have been described by DUKE (1972) and ANDERSON and FUGLSANG (1974).

Testing of the garments was carried out at Bolo village near Kumba in the rain-forest of south-west Cameroon from October 1978 to June 1979; and at Mayo Galké village near Tcholliré in the Sudan-savanna of north Cameroon from August 1978 to February 1979.

Three or four pairs of fly-catching points with equal *S. damnosum* biting densities were chosen along the Dilolo river at Bolo (4°52′N × 9°28′E); and four pairs along the rivers Rey (dry season) and Dokday (rainy season) at Mayo Galké (8°24′N × 14°14′E). Each catching point was separated from the others by a distance of at least 10 m in order to avoid any interference between the fly-collectors.

A staff of six (Bolo 1978) or eight (Mayo Galké, Bolo June 1979) African fly-collectors, all having a long experience of catching *Simulium* flies, worked in groups of two fly-collectors each. Each group of two men worked at one pair of fly-catching points along the river. They were wearing only short-sleeved shirts and short trousers without shoes or socks. There was one set of test garments per group; therefore, one fly-collector in each group always acted as an unprotected control.

All groups worked simultaneously for eight hours every day. The two individuals in each group changed places every two hours and exchanged garments after four hours. After handing on a treated test garment, each fly-collector changed his clothes as well and washed himself throughly with soap and water before resuming work as an unprotected control. Care was taken to prevent the garments being exposed to rain.

The "Deet" repellent[4] and the protective garments are commercially available under the name Shoo-Bug™.[5] The original garments were made of a ¼-inch (6.34 mm) mesh lightweight polyester netting, containing strands of cotton and consisted only of a jacket with a hood (GROTHAUS et al. 1976). However, in view of the low-biting behaviour of *Simulium damnosum*, additional long trousers were made by a local tailor out of the same material in order to provide a more over-all protection for the subjects in the present experiments. By this means the whole body of the fly-collectors, with the exception of the face, the hands and the feet below the ankles, was covered by the test garments.

For one treatment of one set of garments (jacket and trousers) either one bottle (60 cc) or two bottles (120 cc) of "Deet" insect repellent were used. Before testing the freshly-treated garments for the first time, they were allowed to dry in the open air for one hour.

The flies coming to land on the fly-collectors, were caught in hourly samples with a sucking tube ("pooter") and were brought to the laboratory for subsequent identification. Small samples were dissected to determine the parous rate. Flies, coming to land on the face of the fly-collectors, had first to be caught by hand and were than transferred to the sucking tube.

The spatial distribution of the attacking flies on the different parts of the body of a man with and without a test garment was recorded in order to decide whether the flies tended to accumulate on the exposed parts of the body, which were not covered by the untreated or treated test garments.

In the savanna, records were kept of the different parts of the body on which the flies were caught. The face, the hands, and the feet below the ankles were never covered by and clothing and they were therefore always fully exposed to the bites of the flies. For the sake of simplicity, all the rest of the body above the ankles, except the face and the hands, is termed "rest of body" (see tables 3–4). This region of the body was only partially covered by the short-sleeved shirt and the short trousers worn by the control subjects, but was completely protected in the subjects wearing the treated or untreated test garments. Most of the flies on the "rest of body" came to attack the lower legs.

The breeding sites in the savanna adjacent to the catching sites were examined for larvae of *Simulium damnosum* and samples were sent to Dr. C. VAJIME (WHO, Tamale, Ghana) for cytotaxonomic identification.

Temperature and hygrometer readings were made throughout the periods of experiments.

Three series of experiments were carried out:

1. *Pretreatment*: Before the first "Deet"-impregnation of the garments, the reduction of biting density brought about by wearing untreated test garments was compared to the biting density undergone by control subjects, without test garments and clad only in shorts and short-sleeved shirts.

2. *Treated garment a*: After one initial treatment with the "Deet" repellent, the test garments

[4] "Deet" repellent, containing 71.25 % N,N-Diethyl-metatoluamide, 3.75 % other Diethyl-Toluamides and 25.00 % denaturated Ethanol.

[5] Cole Outdoor Products of America, Inc; 801 P Street; Lincoln, Nebraska 68508.

were worn for 8 h a day during a period of up to 12 days of exposure. When not in use, they were kept closed in a plastic bag, so as to prevent the evaporation of the repellent.

3. *Treated garment b*: Identical to experiment 2, but the test garments were hung in the open air when not in use, so as to allow the maximal evaporation of the repellent.

The efficacy of the test garments was calculated as the reduction in the biting density brought about by wearing an untreated or treated garment, according to the formula:

$$\text{Efficacy rating} = \% \text{ reduction or increase} = 100$$

(No. of flies with garment/without garment) × 100 (LINDSAY and MCANDLESS 1978). The formula for the calculation of the 95 % confidence limits of the efficacy rating was taken from the Ciba-Geigy Scientific Tables (1971).

3 Results

3.1 Temperature and saturation deficiency readings in rain-forest and Sudan savanna during the experiments

In the rain-forest the temperature varied during the day between 22 and 30 °C. In the Sudan savanna it varied from 24 to 35 °C during the dry season and from 24 to 30 °C during the rainy season.

Hygrometric readings gave an average saturation deficiency of 0 to 6 Torr in the rain forest. In the Sudan savanna the readings were between 15 and 28 Torr during the dry season and 2 to 10 Torr in the rainy season.

3.2 The repellent effects of untreated and of "Deet"-treated test garments in rain-forest and Sudan savanna

Tables 1 (Bolo: rain-forest) and 2 (Mayo Galké: Sudan savanna) give the daily totals of *S. damnosum* caught on the fly-collectors with and without untreated or treated test garments and the percentage reduction in the biting density on fly-collectors with test garments as compared to those without test garments.

The reduction in the biting density as a result of wearing untreated test garments was found to be 48 % at Bolo in the rain-forest and 46 % at Mayo Galké in the Sudan savanna.

For the "Deet"-impregnated garments a significant repellent effect was taken arbitrarily to be a reduction of over 80 % in biting density. Using this criterion in the rain-forest impregnation of the test garments with 60 cc of the "Deet" repellent had a significant repellent effect only for a short period of up to two days. Impregnation with 120 cc in the rain-forest gave a reduction in biting density of more than 90 % over a period of 5 days exposure (the longest period tested) and this held true whether the garments, which were worn for 8 h a day were kept in a closed plastic bag when not in use or were hung in the open air.

In the savanna, after impregnation with 120 cc "Deet", a significant repellent effect was recorded for up to 7 days when the garments were stored in plastic bags when not in use, but the time dropped to 3 days when the garments were hung in the open air when not in use.

Only garments with a well-marked smell of "Deet" repellent proved to be effectively repellent to the flies. However, the strong smell of a freshly-treated garment was complained of some of the fly-collectors, although no skin reactions were noticed.

Simulium spp. other than *damnosum (S. bovis, S. griseicolle)* were caught in considerable numbers on the fly-collectors only in the savanna during the rainy season (August, September). Apparently, the repellent had more effect

Table 1. Reduction of the *Simulium damnosum s.l.* biting density by wearing untreated or treated test garments as compared to a control without test garments. Results from Bolo (rain-forest)

Date	Day of exposure	No. of flies[1] on the control	No. of flies[2] on collectors with garments	% Reduction[3]
		3 new garments without repellent		
Oct 1978 2 days	–	2775	1431	48.4 (45.0–51.6)
		3 garments impregnated with 60 cc of "Deet" and kept in a plastic bag when not in use		
31/10/78	1	1961	82	95.8 (94.8–96.7)
1/11/78	2	931	167	82.1 (78.8–84.8)
2/11/78	3	1033	321	68.9 (64.7–72.5)
3/11/78	4	1209	301	75.1 (71.7–78.1)
16/11/78	5	452	244	46.0 (36.7–53.9)
17/11/78	6	501	199	60.3 (53.0–66.4)
18/11/78	7	675	436	35.4 (27.0–42.8)
19/11/78	8	681	211	69.0 (63.7–73.5)
20/11/78	9	508	422	16.9 (5.3–27.1)
21/11/78	10	660	360	45.5 (37.9–52.1)
22/11/78	11	454	327	28.0 (16.8–37.7)
23/11/78	12	321	226	29.6 (16.2–40.8)
		2 garments impregnated with 120 cc of "Deet" and kept in a plastic bag when not in use		
26/06/79	1	821	24	97.1 (95.5–98.1)
27/06/79	2	858	32	96.3 (94.6–97.4)
28/06/79	3	1055	64	93.9 (92.1–95.3)
29/06/79	4	1758	120	93.2 (91.8–94.4)
30/06/79	5	1282	119	90.7 (88.8–92.3)
		2 garments impregnated with 120 cc of "Deet" and hung to the open air when not in use		
26/06/79	1	1277	8	99.4 (98.7–99.7)
27/06/79	2	1066	19	98.2 (97.1–98.9)
28/06/79	3	1270	38	97.0 (95.8–97.9)
29/06/79	4	1277	77	94.0 (92.4–95.2)
30/06/79	5	1051	104	90.1 (87.8–92.0)

[1] Control = no test garments, no repellent, fly-collectors wearing only shorts and short-sleeved shirts without shoes and socks. – [2] Garments = group with untreated or treated test garments over shorts and short-sleeved shirts, without shoes and socks. – [3] % Reduction = 100-(No. of flies on collectors with garments/No. flies on control) × 100 (95 % confidence limits).

on these species, but very infrequently did they take a blood-meal, even when present in high numbers.

The cytotaxonomic identification of larvae of the *S. damnosum* complex collected in the savanna showed a predominance of *S. sirbanum* during the dry season and *S. damnosum* sensu stricto during the rainy season, together with a very small percentage of *S. squamosum* (VAJIME, pers. comm.). In the rain-forest near Bolo, it was assumed that all the flies were *S. squamosum* (VAJIME and DUNBAR 1975).

The dissection of small numbers of flies, caught during these experiments on the fly-collectors, revealed an over-all percentage of parous flies of 34 % at Bolo, while at Mayo Galké the parous rate was 58 % during the rainy season

Table 2. Reduction of the *Simulium damnosum s.l.* biting density by wearing untreated or treated test garments as compared to a control without test garments. Results from Mayo Galké (Sudan savanna)

Date	Day of exposure	No. of flies[1] on the control	No. of flies[2] on collectors with garments	% Reduction[3]
		4 new garments without repellent		
Dec 1978 Feb 1979 5 days	–	1071	578	46.0 (40.2–51.3)
		4 garments impregnated with 120 cc of "Deet" and kept in a plastic bag when not in use		
31/08/78	1	247	5	98.0 (94.9–99.3)
1/09/78	2	82	7	91.5 (80.9–96.4)
2/09/78	3	153	0	100 (96.9–100)
8/09/78	4	265	8	97.0 (93.7–98.6)
9/09/78	5	145	22	84.8 (75.8–90.6)
16/09/78	6	199	6	97.0 (93.0–98.8)
17/09/78	7	86	10	88.4 (76.9–94.3)
22/09/78	8	43	19	55.8 (22.1–75.2)
23/09/78	9	109	48	56.0 (37.4–69.1)
29/09/78	10	11	5	54.6 (– 41–86.2)
30/09/78	11	35	7	80.0 (53.0–91.9)
6/10/78	12	37	9	75.7 (47.6–89.1)
		4 new garments impregnated with 120 cc of "Deet" and hung to the open air when not in use		
17/02/79	1	153	9	94.1 (88.1–97.2)
18/02/79	2	424	73	82.8 (77.8–86.7)
19/02/79	3	329	48	85.4 (80.1–89.4)
20/02/79	4	299	187	37.5 (24.6–48.1)
21/02/79	5	336	157	53.3 (43.3–61.5)

[1–3] Explanation see Table 1.

and 52 % at the end of the dry season. No evidence of difference was found in opposition of biting of nulliparous and parous flies.

3.3 The effects of test garments on the distribution of *S. damnosum* bites on the body in the Sudan savanna

Tables 3–4 relate only to the experiments done in the savanna. They show the spatial distribution of the bites of the flies on the face, the hands and the feet (i.e. those areas which are always exposed even when the test garments are worn) and on the "rest of body" (i.e. the parts protected by the test garment). The biting densities and the distribution of bites on a control fly-collector without test garments (i.e. wearing only short trousers and a short-sleeved shirt) are compared with those on collectors wearing (A) test garments not impregnated with repellent, (B) test garments freshly impregnated with repellent and (C) old repellent-impregnated garments. For this purpose freshly-impregnated garments were considered to be those treated up to 7 days previously, when the garments were kept in plastic bags when not in use, and those treated up to 3 days previously, when the garments had hung in the open

air when not in use. Old impregnated garments were those treated 8 to 12 days previously (for those kept in plastic bags) and 4 to 5 days previously (for those hung in the open air).

Table 4 presents the number and distribution of those flies, that came on the fly-collectors wearing test garments during the period of time that 100 flies were caught on the control collectors, too. The efficacy rating (i.e. the reduction or increase in the biting density by wearing a garment) is given for each part of the body and 95 % confidence limits are shown in brackets.

Table 3. Distribution of the bites of the flies over the body: Numbers and percentages of flies, caught on different parts of the body of the fly-collectors

No. of flies	face (%)	hands (%)	feet (%)	"rest of body" (%)[1]	total
A. *Untreated test garments (46 % reduction)*					
Results from 5 days of catching					
Test garments, no repellent	1 (0.2)	39 (6.8)	371 (64.2)	167 (28.9)	578
Control	0 (0.0)	32 (3.0)	256 (23.9)	783 (73.1)	1071
B. *Freshly-treated test garments (91 % reduction)*					
Results from 10 days of catching					
Test garments, fresh repellent	3 (1.3)	8 (4.1)	160 (81.2)	26 (13.2)	197
Control	2 (0.1)	51 (2.3)	574 (25.4)	1632 (72.2)	2259
C. *Old treated test garments (65 % reduction)*					
Test garments, old repellent	1 (0.3)	47 (13.4)	224 (64.0)	78 (22.3)	350
Control	0 (0.0)	29 (2.9)	198 (20.0)	765 (77.1)	992

[1] See text.

Table 4. Number and distribution of the flies that came to bite the fly-collectors wearing test garments during the period of time when 100 flies were caught on the control collectors. % increase or reduction in the biting density by wearing a garment (95 % confidence limits)

No. of flies	face	hands	feet	"rest of body"[1]
A. *Untreated test garments, no repellent*				
Test garments, no repellent	0,1	3,6	34,6	15,6
Control	0	3,0	23,9	73,1
Efficacy rating[2]	–	−22 %	−45 %	+79 %
(95 % confidence limits)	–	(−99 to +25)	(−70 to −23)	(+75 to +82)
B. *Freshly-treated garments*				
Test garments, fresh repellent	0,15	0,4	7,1	1,2
Control	0,10	2,3	25,4	72,2
Efficacy rating[2]	−50 %	+84 %	+72 %	+98 %
(95 % confidence limits)	(−1178 to +79)	(+66 to +93)	(+67 to +77)	(+98 to +99)
C. *Old treated garments*				
Test garments, old repellent	0,1	4,7	22,6	7,9
Control	0,0	2,9	20,0	77,1
Efficacy rating[2]	–	−62 %	−13 %	+90 %
(95 % confidence limits)	–	(164 to +0,2)	(−38 to +7)	(+87 to +92)

[1] "Rest of body" see text. – [2] Efficacy rating: formula see text, − ≙ increase, + ≙ reduction. The increase or reduction in the biting density is not significant at the $p = 0{,}05$ level, if the 95 % confidence limits include 0.

On the control collectors, less than 3 % of all flies came to the face and hands, 20–25 % attacked on the feet below the ankles and 72–77 % were caught on the other parts of the body. Most of the latter came to bite the lower legs and very few bit above the waist. The reduction of biting density on a person wearing the untreated test garments indicates that most of those flies that would otherwise have bitten the parts of the body now covered by the test garment did not move to bite the few remaining unprotected areas of the skin. Only on the feet below the ankles were significantly more flies (45 % increase) caught. On the hands the increase was not significant at the $p = 0.05$ level, and on the face it was not significant.

During the period of repellent efficacy very few flies were caught on the freshly-treated test garments and the numbers of flies coming to the uncovered hands and feet, were very significantly reduced owing to the spatial action of the repellent (table 4, B).

With an old treated garment the repellent no longer had any spatial action and, in addition, the number of flies caught on the test garments increased (table 4, C).

4 Discussion

The conception of wearing jackets impregnated with insect repellent as a protection against blackflies and the transmission of onchocerciasis in West Africa has to be specially adapted to the typical low-biting behaviour of the vector species there, as well as to the general living conditions in undeveloped areas. Additional long trousers are necessary to protect the legs since, in the savanna, less than 5 % of flies bit above the waist (pers. obs.) and, in the forest, only 0–2 % are attracted to the same parts of the body of a person standing in an upright position (DUKE and BEESLEY 1958). Furthermore, *S. damnosum* does not try to crawl under, or bite through, normal clothing, and there was no marked tendency of the flies in the savanna to concentrate in high numbers on the upper, unprotected parts of the body of a person wearing an untreated or treated protective garment.

The choice of a control in the form of a fly-collector wearing only short trousers and a short-sleeved shirt, without shoes or socks, certainly presents a near maximal exposure and probably provides a maximum estimate of the biting density. The normal clothing of the local populations in the study areas varied, according to age, sex, occupation and tribe, from almost nothing to a more or less complete covering, including shoes, socks, long trousers, long shirts and covered head. Onchocerciasis, however, is typically a disease of farmers, ferrymen and fishermen in rural regions, in short all those having a close contact with *Simulium*-infested rivers. Very few of them wear shoes and socks or long trousers, especially when working in their fields or when they come to the river for washing, fishing or hunting.

A reduction in fly biting density of at least 80 % may be considered as the minimum value necessary for recommending the use of any special protective garment against *Simulium damnosum* either as a biting pest or as a vector of *Onchocerca volvulus*. Only impregnation with 120 cc of "Deet" repellent could guarantee this level of protection for a period of about one week, if the garment was used during all out-door activities and provided that the time of exposure did not exceed 8 h a day and that the garment was kept in a plastic bag when not in use. However, even a freshly-treated garment did not provide

100 % protection, although the number of flies coming to the uncovered parts of the body was greatly reduced through the spatial action of the repellent.

The quick drop in the repellent activity of treated garments in the savanna, when the garments were left continuously exposed to the open air, was not seen in the forest. A higher evaporation rate of the repellent drug during the hot dry season in the savanna or a higher sensivity of the forest *(Simulium squamosum)* flies to the repellent, or both effects together, might have been responsible for this result. THOMPSON (1976) suggested, that *Simulium damnosum* s. str. and *S. sirbanum* in the savanna are hunting mainly by sight whereas *Simulium squamosum* in the Cameroon rain-forest hunts mainly by smell.

The Scientific Advisory Panel (SAP) of the Onchocerciasis Control Programme in the Volta River Basin has recommended (SAP 1977), that an annual *S. damnosum* biting density of 1,000 flies/man/year should be considered as an indication of the maximum tolerable level for the transmission of *O. volvulus* in the West African savanna. At this level the disease may still be endemic, but no serious eye lesions occur. With a maximum annual biting density of more than 600,000 flies at Bolo (DUKE 1972) and 40,000 to 80,000 flies at Mayo Galké (RENZ, pers. obs.) wearing "Deet" impregnated garments alone would not be sufficient to prevent people from becoming infested with *O. volvulus* at a level of intensity that could produce serious eye lesions. Only with the additional protection of shoes and socks could these garments possibly provide enough protection, since more than 80 % of all flies coming to bite a man wearing the treated garments were biting on the feet below the ankles.

Our observations at Bolo indicate that the high biting densities in the forest predisposed the local populations to accept the garments for out-door activities despite their rather ludicrous appearance. At Mayo Galké in the Sudan savanna, on the other hand, the biting densities are not high enough to prompt the population to accept the use of the garments. Even with a high prevalence of eye lesions, due to onchocerciasis, the people are not yet generally aware that the bites of the flies are responsible for spreading the disease; or, if they are so aware, they are not sufficiently motivated to take regular personal protective measures of this kind.

Although during these experiments the garments were used only for a short period of time and for light work, they showed signs of serious wear, especially the trousers. Probably, the life-span of the material could hardly exceed one month under rough conditions, even though small tears in the garment will not affect its efficacy.

The high costs of one repellent treatment (US $ 2.40), the need to repeat this at weekly intervals, and the short life-span of the garments would probably limit their application to people, who have to make brief visits to areas highly infested with *S. damnosum* and who are aware of the danger of their bites. For the local African populations in endemic areas – children, peasants, fishermen and ferrymen – the use of repellent-impregnated garments would be beyond their financial means and, in their present form, not very practicable. Nor would the benefit of the protection afforded be appreciated, as long as the biting density is not really considered to be disturbing and the danger of transmission is not understood.

The present experiments do suggest, however, that normal western European-style clothing, of shoes or boots, socks or stockings, long trousers and a shirt (preferably) long-sleeved, or African-style clothing giving similar cover-

age, is likely to provide a high degree of protection from the bites of *S. damnosum*. The majority of the flies that are prevented from biting on the feet and lower legs (their sites of preference) continue to attack and settle on these parts of the body when they are covered with clothing. Relatively few of them move upwards to attack the exposed hands, forearms and face. In so far as it is practicable and consistent with carrying out rural occupations in the tropics, it would appear that wearing clothing, which adequately prevents acurs of *S. damnosum* to the legs of man, will greatly reduce the exposure rate to the bites of this insect and will thus constitute a major personal preventive measure against onchocerciasis. If whole populations could be persuaded to protect themselves in this way it is a moot point whether the selection pressure so produced on *S. damnosum* would lead the flies to bite higher on the body or to an increased degree of zoophily.

Acknowledgements

We wish to express our thanks to the Office National de la Recherche Scientifique et Technique, Yaoundé, Cameroon, for the support of this work. We are specially indepted to our staff of fly-collectors in the savanna and rain-forest, who tested the garments in the field, and to Messrs OGUAMA and NOUDJINGAR, who assisted us in the laboratory. Our thanks also extend to Dr. C. VAJIME, Tamale, for the cytotaxonomic identification of the larval samples, to Prof. K. DIETZ, Tübingen, for help with the statistical analysis of the data and to Dr. B. O. L. DUKE, Geneva, for reading the manuscript.

Zusammenfassung

„Deet"-Repellent-imprägnierte Kleidung als individueller Schutz gegen Simulium damnosum s. l., die Überträgermücken der Onchozerkose in Savanne und Regenwald Kameruns

Diäthyl-toluamid(„Deet"-)imprägnierte Kleidung wurde in Gebieten mit hyperendemischer Onchozerkose zum Schutz vor *Simulium squamosum* im Regenwald und *S. sirbanum/S. damnosum* s. str. in der Savanne erprobt.

Die aus einem groben Netzgewebe gefertigte Schutzkleidung (lange Hosen und Jacke mit Kapuze) verringerte nach Imprägnierung mit 120 cc „Deet" die Mückenanflugdichte während der ersten 5–7 Tage (40–56 h Exposition) um rund 90 %, verglichen mit einer Kontrollgruppe ohne Schutzkleidung, die nur kurze Hosen und kurzärmelige Hemden trug. Danach fiel die Schutzwirkung rasch auf den Wert einer nicht-imprägnierten Schutzkleidung, d. h. auf 47 % Reduktion der Anflugdichte. Bei diesen Versuchen wurde die Schutzkleidung 8 h pro Tag getragen und bei Nichtgebrauch in einem Plastiksack luftdicht aufbewahrt. Ganzzeitige Exposition führte zu raschem Nachlassen der Repellent-Wirkung innerhalb von 3 Tagen in der Savanne, wohingegen im Regenwald die volle Wirksamkeit über 5 Tage beibehalten wurde; länger wurde sie dort nicht erprobt.

Weniger als 3 % aller Mücken, die einen Menschen ohne Schutzkleidung anflogen, landeten auf dem Gesicht oder auf den Händen. Der Anflug an diesen Körperregionen wurde weder durch das Tragen nicht-imprägnierter noch imprägnierter Schutzkleidung signifikant erhöht. Dagegen führte die Bedeckung des Beines durch die nicht-imprägnierte Schutzkleidung zu einer Erhöhung der Anflugdichte um 45 % am unbedeckten Bein unterhalb des Knöchels, wo bei der Kontrolle ohne Schutzkleidung 24 % der gesamten Anflugdichte gemessen wurden. Nach Imprägnieren der Schutzkleidung reduzierte sich der Anflug auch an diesen nicht von der Kleidung bedeckten Körperregionen durch die räumliche Wirkung des Repellents während der ersten Tage um 72 bis 84 %.

References

ANDERSON, J.; FUGLSANG, H.; HAMILTON, P. J. S.; DE C. MARSHALL, T. F., 1974: Studies on onchocerciasis in the United Cameroon Republic. II: Comparison of onchocerciasis in rain-forest and Sudan savanna. Trans. Roy. Soc. Trop. Med. Hyg. *68*, 209–222.

Ciba-Geigy, 1971: Scientific Tables. 7th ed. Basle p. 186.

DUKE, B. O. L.; BEESLEY, W. N., 1958: The vertical distribution of *Simulium damnosum* bites on the human body. Ann. Trop. Med. Parasitol. *52*, 274–281.

DUKE, B. O. L.; MOORE, P. J.; ANDERSON, J., 1972: Studies on factors influencing the transmission of onchocerciasis. VII: A comparison of the *Onchocerca volvulus* transmission potentials of *Simulium damnosum* populations in four Cameroon rain-forest villages and the pattern of onchocerciasis associated therewith. Ann. Trop. Med. Parasitol. *66*, 219–234.

FROMMER, R. L.; CARESTIA, R. R.; VAVRA jr., R. W., 1975: Field evaluation of Deet treated mesh jacket against black flies (Simuliidae). J. Med. Entomol. *12*, 558–561.

GROTHAUS, R. H.; HASKINS, J. R.; SCHRECK, C. E.; GOUCK, H. K., 1976: Insect repellent jacket: status, value and potential. Mosqu. News *36*, 11–18.

LINDSAY, I. S.; MCANDLESS, J. M., 1978: Permethrin-treated jackets versus repellent-treated jackets and hoods for personal protection against blackflies and mosquitoes. Mosqu. News *38*, 350–356.

SCHIEFER, B. A.; VAVRA jr., R. W.; FROMMER, R. L.; GERBERG, E. J., 1976: Field evaluation of several repellents against black flies (Diptera: Simuliidae). Mosqu. News *36*, 242–247.

SCHMIDT, M. L., 1977: Relative effectiveness of repellents against *Simulium damnosum* (Diptera: Simuliidae) and *Glossina morsitans* (Diptera: Glossinidae) in Ethiopia. J. Med. Entomol. *14*, 276–278.

Scientific Advisory Panel of the Onchocerciasis Control Programme, Conclusion, Wld Hlth Org. (1977) OCP/SAP/77.

THOMPSON, B. H., 1976: Studies on the attraction of *Simulium damnosum* s. l. (Diptera: Simuliidae) to its hosts. I. The relative importance of sight, exhaled breath and smell. Tropenmed. Parasitol. *27*, 455–473.

VAJIME, C. G.; DUNBAR, R. W., 1975: Chromosomal identification of eight species of the Subgenus *Edwardsellum* near and including *Simulium (Edwardsellum) damnosum* Theobald (Diptera: Simuliidae). Tropenmed. Parasitol. *26*, 111–138.

Addresses of the authors: ALFONS RENZ, Dipl.-Biol., Tropenmedizinisches Institut der Universität Tübingen, Wilhelmstr. 31, D-7400 Tübingen; PETER ENYONG, B. Sc. Entomologist, Medical Research Center, P.O. Box 55, Kumba, United Rep. of Cameroon