

Early in December, the epidemic reached such proportions that the island commander dispatched one hundred native grass cutters to the hospital area and twenty large trucks for hauling sand. Up to that time (first week in December) more cases had been developing in area 1 (general hospital) than in area 2 (station hospital). The work was started first in the general hospital area. Immediately the incidence in the station hospital area increased. We feel that the rodents migrated from area 1 over to area 2, seeking cover in grass still standing in area 2. During the period when area 1 was cleared and area 2 was untouched, the rate of incidence in the two areas switched. Area 2 cases increased, while area 1 decreased. Then, when work began on area 2, the incidence again declined. This was all in conjunction with a vigorous rat-trapping campaign.

SUMMARY

The disease on this island reached epidemic proportions and showed a virulence out of comparison with that found on nearby islands. Evidence pointed to the rat as the important animal host; in addition, the lizard was strongly suspected. Infested areas were sharply demarcated. There appeared to be some seasonal connection. Incidence among personnel working in the hospital mess was abnormally high. The epidemic subsided abruptly after control measures were initiated.

Control of Sandflies with DDT ✓

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MAJOR MARSHALL HERTIG

Sanitary Corps, Army of the United States
and

FIRST LIEUT. ROBERT A. FISHER

Sanitary Corps, Army of the United States

The control of sandflies of the genus *Phlebotomus* has been notoriously unsatisfactory. Experiments during the past summer, however, have shown that DDT is an effective weapon against this group of troublesome and disease-carrying insects. That this method of control may be better understood, pertinent phases of the life-cycle and behavior of sandflies are outlined.

Sandflies of the genus *Phlebotomus* should not be confused with those of the genus *Culicoides*, which are also abundant and troublesome in certain regions but belong to another family and differ widely from *Phlebotomus* in many respects. The control methods described are not applicable to *Culicoides* so far as is known. It is important to be able to recognize *Phlebotomus* as such, and to discover the principal daytime hiding places. Sandflies of the genus *Phlebotomus* are small, hairy midges, 2 to 3 mm. long, easily recognized by the position of the wings,

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which are elevated and spread to form a "V." They readily penetrate ordinary screens or nets and are almost entirely nocturnal. Only the females suck blood. At night sandflies may be found both indoors and out, feeding on man or animals or resting on walls nearby. During the day they seek a variety of shelters. They may be found in the darker corners and near the ceiling of sleeping quarters. The commonest outdoor shelters are masonry cracks, stone walls, excavations, animal burrows, hollow trees, and deep cracks in soil. Sandflies are easily seen on light-colored walls; however, in searching for them on rough, dark surfaces or in recesses, tobacco smoke is helpful since it causes them to move and thus reveal themselves.

The breeding places are difficult to demonstrate but typically are in loose soil or organic debris beneath stones, in masonry cracks, etc., in much the same kinds of places as the outdoor shelters. In open country free of stones they may breed in animal burrows or in open soil. The flight range is believed not to exceed 100 to 200 meters where breeding places are near human habitations. However, in open country with breeding places associated with widely scattered rodent burrows, flight ranges of 1,500 meters have been measured.

Those species whose habits have been studied tend to progress by means of short flights, alighting on stones, plants, and other obstacles as they approach a house. Instead of entering at once, sandflies tend to alight on the outer walls and then in a series of short, hopping flights with relatively long pauses make their way into the building. Once inside they may rest on the walls some time before attempting to feed. A similar lack of haste has been observed as sandflies emerge from stone walls during the first hours of darkness. They may rest at the entrances to such shelters as much as half an hour before taking flight. These flight habits render sandflies vulnerable to the residual action of DDT. The surfaces on which sandflies must alight and on which they spend considerable time are easily accessible and can be transformed into lethal traps or barriers.

EXPERIMENTAL WORK

In laboratory tests carried out in Italy it was found that contact with DDT gave knockdown without recovery in from six to fifteen minutes in the case of *Phlebotomus perniciosus* and *P. parroti* var. *italicus*, while *P. papatasi* required fifteen to forty minutes. In all cases agitation was noted within a few minutes, while fluttering of the wings and lack of coordination were frequent after about six minutes. The effect on feeding habits of those affected but not killed has not been determined.

Following preliminary control studies in Italy, more extensive experiments were carried out in Palestine near the Dead Sea. Professor S. Adler, of Hadassah University, Jerusalem, suggested the selection of this area where he had carried on sandfly work for many years and which offered peculiar advantages for

control studies. The British Medical Service furnished personnel, transportation, equipment, and much of the material. Field headquarters were established at the plant of Palestine Potash, Limited, at the north end of the Dead Sea.*

Phlebotomus in the Dead Sea area. The floor of the Jordan Valley near the Dead Sea (1,300 feet below sea level) is a flat expanse of salt desert, uninhabited except in small irrigated areas and at various installations, such as the Potash Works, along the shore of the Dead Sea. Sandflies, consisting almost entirely of *P. papatasi*, are abundant. They have been found in great numbers in places a mile from any human habitation. Cutaneous leishmaniasis is endemic in the area and is transmitted by *P. papatasi*. The desert is dotted with shrubs beneath which are found many rodent burrows. The breeding places of *Phlebotomus* in this region have not been studied, but the situation may prove to be similar to that in Transcaucasia where *P. papatasi* has been found breeding in rodent burrows, with the rodents apparently serving as their principal hosts and as reservoirs of cutaneous leishmaniasis.

Our principal experimental work was done at the Jewish Agricultural Settlement a mile north of the Potash Works. The living quarters consisted of about a dozen small four-room bungalows of uniform size and construction (smoothly finished cement), and with a uniform, abundant sandfly population. The houses were surrounded for the most part by bare, uncultivated soil. Houses were sprayed with DDT in the following ways: (1) inner walls and edge of ceiling, the window screens being protected from spray; (2) outer walls from ground to eaves, including doors, windows, and screens; (3) outside of openings only, i.e., doors, windows, screens, and a foot or two of the surrounding wall. The results were judged



Living quarters, Jewish Agricultural Settlement, Dead Sea, Palestine, where sandfly-control experiments with DDT were carried out.

by comparing sandfly counts of sprayed and control houses, and by the bites reported by the occupants. In all cases the DDT

*Generous material aid was given by these organizations and many kindnesses were extended by Professor Adler, the officers of the British Medical Service and of the Potash Company, and others who followed the work closely and aided in many ways.

was applied as a 5 percent solution (by weight) in kerosene, at the rate of 1 to 1.5 gallons per thousand square feet.

Inside spraying gave perfect or near-perfect control with no bites reported. Spraying the outside of the openings only and spraying the entire outside both reduced the sandflies to about one-quarter the control counts, with very few bites reported. Comparable results were secured in experiments on a smaller scale at several other places in the region. The duration of the effectiveness of the treatment, which was undiminished during the twenty-four days of observation, is still to be determined.

A tent-spraying experiment at the Settlement, in which about one-half of twenty conical, double-walled tents were treated either inside or both inside and out, was interrupted by the onset of winter rains and high winds. Those observations which it was possible to make gave promising indications that tent-spraying may be as effective as house-spraying.

RECOMMENDATIONS

On the basis of the Dead Sea experiments with *P. papatasi* and the previous work in Italy with several species, we make the following tentative recommendations for the protection of occupants of buildings (sleeping quarters and rooms occupied after dusk, such as offices, control rooms, day rooms, mess halls, and clubs): *Spray the inner walls from floor to ceiling and as much of the ceiling as possible. Spray especially well the corners and upper part of the walls, the doors, windows, and screens. For greater margin of protection, spray also the outside of the openings (doors, windows, screens, ventilators, etc.) together with a foot or two of the surrounding wall.*

In the case of tentage it is suggested that, on an experimental basis, tents be sprayed inside, together with the outside of openings, i.e., door or flap, bottom edge, and ventilating holes.

The above measures depend entirely on killing sandflies or diverting them from a blood meal at the time they enter a building. The walls treated with DDT thus constitute a protective barrier and the method does not involve the destruction of sandflies either at their breeding places or outdoor shelters. With the limited objective of protecting persons indoors, the spraying of buildings has proved remarkably effective not only in our experimental work but in a number of instances where we have had the opportunity to observe the effect on sandflies of DDT applied for other purposes.

Persons out-of-doors should protect themselves by means of repellents and proper clothing. The repellent issued by the Army has been shown to be effective against *Phlebotomus*. Sandflies do not readily bite through ordinary clothing, although they may crawl beneath the trousers and bite through or above the socks.

In experiments in Italy and Palestine, spraying houses only on the outside was designed to test the possibility of reaching the

sandflies before they could enter and in addition, by treating also nearby resting places and potential breeding places, to destroy them at their source. Preliminary results indicate that where buildings are of masonry with many cracks, with nearby stone walls and rubble heaps, i.e., where shelters and breeding places are closely associated with human habitations, outside spraying alone gives a high degree of control. Under such circumstances it is quite possible that the proper selection of outdoor surfaces to be treated may give localized area control, with protection for persons both indoors and out. In one experiment carried out by Professor Adler at a village in northern Palestine, sandflies could be collected in great numbers on the stone walls of a courtyard during the early hours of darkness. A portion of the wall was sprayed with DDT, after which no sandflies at all were seen on the sprayed portion, while normal numbers continued to appear on the unsprayed part. This and other experiments indicate the possibility of completely denying to sandflies their principal outdoor shelters and breeding places. The larvae, protected by soil and debris at some distance from the entrance to the breeding places, would not be affected, but the adults would be destroyed on entering or leaving. The long life cycle of *Phlebotomus*, usually two or three months or more, and the consequently low replacement rate, combined with the constant destruction of sandflies at the DDT-treated surfaces of shelters, breeding places, and barriers between them, and their hosts, would all favor the achievement of area control.

Obviously, the limits of effectiveness of the various methods of applying DDT are still to be worked out, as well as the adaptation of methods to local situations. In certain areas, such as at the Dead Sea, breeding places are apparently in open soil and possibly at considerable distances from houses. No method of attacking such breeding places has been worked out. In these cases control methods would necessarily be limited to house-spraying, of which the most effective single method has proved to be inside spraying. On the other hand, in the more common or even "classical" type of sandfly situation, with breeding places in masonry, under stones, in stone walls, and in any case closely associated with human habitations, outside spraying may serve not only for the protection of houses but in addition be extended to area control. Where malaria is also a problem, as it often is in sandfly regions, the joint objective of controlling both would dictate inside spraying in any case.

Further investigation on at least a village scale is desirable at this time to work out the practical applications of "house control" and to explore the possibilities of area control. It would also be desirable, wherever house-spraying with DDT is being carried on as an antimalaria measure, to evaluate its effect on any sandflies that may be present as well.