ARTICLES

EXPLORATORY STUDIES ON THE CONTROL OF ADULT MOSQUITOES AND BLACKFLIES WITH DDT UNDER ARCTIC CONDITIONS [1]

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Tests with both light and heavy aircraft and other types of equipment for the dispersal of DDT in the control of adult mosquitoes have been reported by Deonier *et al.* (1945), Lindquist *et al.* (1945), the Army Air Forces Committee on Aerial Dispersal of Insecticides (unpublished), and many others. To determine whether such methods of area control of adult insects would be applicable under arctic conditions, the authors undertook a preliminary test program during the summer of 1947 at Churchill, Manitoba, Canada. The program included exploratory studies on the control of adult mosquitoes, of arctic and subarctic species, and blackflies by means of aerial and ground dispersal equipment to obtain information relative to the suitability of methods and equipment, as well as dosages of DDT necessary for control under conditions of the far north. Additional work was devoted to the possibility of obtaining temporary control and protection from mosquitoes and blackflies by treating small areas with aerosol bombs, smoke bombs, and hand-spraying equipment. The results of these studies are given in this paper.

Test Conditions.—Aerial spray tests were conducted on both open tundra and swampy forest typical of the Churchill area. The open tundra was flat and marshy, with low-growing vegetation, predominantly lichens, mosses, and grasses. The forested tract consisted of thin stands of larch and spruce 15 to 30 feet in height intermixed with thin to dense stands of dwarf willow and birch 2 to 6 feet in height. The whole formed only a relatively light vegetative canopy, as compared with the average forest or jungle, and presented no real obstacle to penetration with sprays applied from ground or air. Aerial spray plots embraced from 300 to 1,700 acres of such terrain. Other tests conducted on similar terrain involved small areas of 1 to 2 acres treated with hand sprayers to over 100 acres treated with a power sprayer.

The aerial spray tests were conducted early in July when adult mosquito populations were very large and rapidly increasing. Larval and pupal populations were fairly high but were declining. Although only a few blackfly adults were present at this time, streams within the plots contained an abundance of immature stages. During the latter half of July, small-scale tests with hand sprayers, aerosol and smoke bombs, and a power sprayer were made when adult mosquito populations had reached their peak or were declining, but when blackflies were abundant and apparently increasing.

The weather was relatively mild during the period in which aerial spray tests were conducted. The maximum daily temperatures ranged from 52° to 64° F. Wind

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velocities varied, but, with one exception, tests were carried out when winds were less than 10 m.p.h. The small-scale tests were conducted under much the same meteorological conditions except that periods with wind velocities generally exceeding 10 m.p.h. were selected to facilitate dispersion of the insecticide.

Methods and Materials.—Four aerial dispersal tests were made with a R. C. A. F. Dakota (C-47) aircraft equipped with cargo tanks and a simple gravity-flow discharge device consisting of a vertical, round, 3⅜-inch pipe extending 14 inches below the fuselage. The discharge pipe was cut at an angle of 45 degrees at the side facing the tail of the plane to minimize the flow interference during flight. The average discharge rate was 94 imperial, or 112 U. S. gallons per minute. In flight the flow of liquid streamed just below the fuselage, but much of it impinged upon the tail assembly and was swept off by air turbulence. The size of particles, as determined by measurements from a series of white cards, ranged from 40 to 1,360 microns in diameter, the average being approximately 250 microns. A 5 per cent DDT-fuel-oil solution (wt./vol.) was used in all the tests. Since the rate of discharge could not be changed, a change of dosage was obtained by varying the swath interval from 100 to 200 yards. Except for the first test, the height of flight was maintained as nearly as possible at 100 feet.

The pound-per-acre deposition of DDT, as shown in table 1, was computed from the discharge rate of the equipment employed. This figure gives only the total amount of material released, but the effective DDT dosages are probably much lower.

A power sprayer was not available for ground test work, but a suitable unit was constructed, consisting of a gear pump powered by a ¼-hp. gasoline engine and a 12-foot vertical boom equipped with six mist-spray nozzles. This equipment was mounted on a "Weasel," cargo carrier, M-29, with the top outlet being approximately 16 feet from the ground. When operated at a pressure of 50 pounds per square inch, this unit dispersed approximately 2 gallons of solution per minute. Two tests were conducted with this sprayer at a dosage of approximately 2 U. S. quarts of 10 per cent DDT-xylene-fuel-oil solution (approximately 0.35 pound of DDT) per acre. The swath interval varied from 150 to 200 yards, depending upon wind velocity.

Mosquito populations were estimated at established counting stations in each plot before spraying and at intervals thereafter until adult abundance rose to a level equal to that of untreated check areas. Relative abundance was determined by counts of those landing on the front of a man's trousers over a period of 1 minute. The percentage control of adults was calculated on the basis of counts before and after treatment, but check areas were kept under observation to confirm the fact that reductions were due to treatments and not to natural factors. This routine was also followed in evaluating small-plot tests, except that observations were made immediately and at shorter intervals after treatment.

Aerial Spray Tests.—The detailed results of the four tests are presented in table 1. In the first test there was no significant reduction of mosquitoes 24 hours after treatment. After 48 hours mosquitoes were more numerous than prior to the treatment. Several reasons may be advanced for this failure, namely, inadequate dosage due to the wide swath interval, excessive flying height, insufficient atomization of the spray solution, or rapid reinvasion of the plot from surrounding heavily infested areas.

In the second test an extremely heavy population of adult mosquitoes was almost completely eliminated for 4 days after spraying, but thereafter infiltration was so rapid that the population was fully restored within 8 days.

In test 3 the swath interval was the same as in test 1 (600 feet), but the area covered was twice as large and the height of flight was less than 100 feet. There was no reduction of adults 6 hours after treat-

TABLE 1.—Results of aerial spray tests with a 5 per cent DDT-fuel-oil solution against adult mosquitoes of arctic and subarctic species.

Plot Number	Type of Vegetation in Area	Size of Plot (Acres)	Average Temperature (° F.)	Wind Speed (M.p.h.)	Height of Flight (Feet)	Swath Interval (Feet)	Dosage per Acre		Per Cent Reduction of Adults at Indicated Intervals After Treatment					
							DDT (Pound)	Oil [1] (Gallon)	6 Hours	24 Hours	48 Hours	4 Days	6 Days	8 Days
1	Dwarf birch and willow; scattered spruce-larch	310	54	2.5–5.0	123–202	600	0.26	0.51	–	12.5	0	–	–	–
2	Largely spruce-larch forest	728	60	4–8	50–180	300	.48	.96	99.8	–	99.8	99.1	84.0	0
3	Mixed spruce-larch wood and dwarf birch and willow	654	52	8–10	45–90	600	.26	.51	0	92.0	70	0	–	–
4	Camp area, sparsely wooded ridge and tundra	1,781	64	10–28	50–180	300	.44	.89	–	79.0	–	0	–	–
Control	Similar to plots 1, 2, and 3	–	–	–	–	–	–	–	0	0	0	0	0	0
	Similar to plot 4	–	–	–	–	–	–	–	0	0	–	60	–	–

[1] Imperial gallons.

ment, but after 24 hours the count declined 92 per cent. The population was fully restored 4 days after treatment. Since the actual time of spraying in test 3 overlapped that of test 2, and the population recovery in test 3 was much faster than that in test 2, it is possible that the recovery in test 3 was due mainly to emergence of unaffected immature stages rather than to rapid infiltration. About half this area was covered with vegetation, and the stand was much thinner than in test plot 2.

In test 4 the spraying operation was the same as in test 2, but the wind velocity was higher. A 79 per cent reduction of adult mosquitoes was indicated 24 hours after treatment, but the population was restored within 4 days.

The best results were obtained in test 2, in which the DDT discharge rate was about 0.5 pound per acre, the swath interval was 300 feet, and the area was more or less forested. Apparently the swath widths in tests 1 and 3 were excessive as compared with the delivery rate of the plane equipment and the rather large droplet sizes. The ineffectiveness of the fourth test was probably due principally to the high wind velocity, which in the absence of vegetation prevented normal settling of the small particles of spray. In test 2 the heavier stand of trees and bushes, which served as a windbreak, probably permitted the settling of a large proportion of the finer spray droplets, and may also have retarded the rate of mosquito reinfiltration. Under these relatively favorable conditions, however, the protection afforded by covering a square mile was little over a week's duration.

Power Sprayer Tests.—Tests with ground-operated power equipment were carried out on two plots, one of 118 acres and one of 130 acres, at a dosage of 0.35 pound of DDT per acre. In the first test the reduction of mosquitoes and blackflies after 24 hours was 99.8 per cent. Within 48 hours, however, infiltration from surrounding areas had commenced, and 4 days after treatment the landing rates were again estimated at 100 plus per minute. In the second test the 48- and 72-hour counts showed a reduction of 81 per cent, but the general mosquito population declined so rapidly at this time that the results were of little significance. This decline of the general mosquito population probably indicated the natural ending of the "mosquito season."

Incidental observations indicated that tabanids were affected little, if at all, by the sprays. Blackflies tended to reinfest the sprayed plots quicker than mosquitoes, but their activity was too sporadic to permit satisfactory counts.

Small-Plot Tests.—Four tests were conducted on lightly forested plots 1 to 2 acres in size. Dosages of 1 to 2 quarts per acre of DDT-fuel-oil solution were applied with a knapsack-pressure sprayer equipped with a mist-producing nozzle. The swath intervals were about 30 feet. The higher dosage provided an effective, but only temporary, reduction of mosquitoes and blackflies. Infiltration began almost immediately after spraying, and a heavy population was restored within 15 minutes to an hour. The blackflies, in annoying numbers, appeared to return to the treated areas sooner than the mosquitoes. Similar results were obtained in tests with pyrethrum and pyrethrum-DDT aerosol bombs, and with DDT-nicotine and benzene hexachloride smoke bombs. In each case, protection lasted only for a brief period. It was concluded, therefore, that small-area treatments of this type, which have been reported as effective in jungle or heavily forested areas (Gorgas Memorial Laboratory, p. 23), were of little value under the conditions at Churchill.

Summary.—In a cooperative study of mosquito control at Churchill, Manitoba, Canada, four aerial spraying tests with DDT were conducted with a R. C. A. F. Dakota (C-47) airplane against adult mosquitoes. In one test on a forested plot a mile square treated at the discharge rate of about 0.5 pound of DDT per acre, excellent control was obtained for 4 to 6 days, after which the plot became reinfested. The swath interval was 300 feet and the flying height approximately 100

feet. A similar treatment over open terrain and at higher wind velocities did not give effective control. With two treatments at a discharge rate of 0.26 pound of DDT per acre and a swath width of 600 feet, no reduction occurred in one of the plots and only temporary reduction in the other.

Two plots of 118 and 130 acres were treated with a ground-operated power sprayer at a dosage of 0.35 pound of DDT per acre. One treatment effectively reduced the number of both mosquitoes and blackflies for 24 hours, but reinfestation began within 48 hours. The results of the second test were questionable because a natural reduction occurred in untreated areas.

Small-plot tests with DDT sprays, pyrethrum and pyrethrum-DDT aerosols, and DDT-nicotine and benzene hexachloride smoke bombs gave temporary reduction of mosquitoes and blackflies, but the plots became reinfested within 15 minutes to an hour, an indication that such measures were of little practical use. The blackflies appeared to return into the treated areas sooner than the mosquitoes.

Literature Cited

DEONIER, C. C., AND R. W. BURRELL. 1945. Airplane application of DDT larvicides. *Jour. Econ. Ent.* 38(4): 425–427.

GORGAS MEMORIAL LABORATORY. Seventeenth Annual Report (1944). 79th Congress, First Session, House Doc. No. 15, 32 pp.

LINDQUIST, A. W., A. H. MADDEN, C. N. HUSMAN, AND B. V. TRAVIS. 1945. DDT dispersed from airplanes for control of adult mosquitoes. *Jour. Econ. Ent.* 38(5):541–544.

HEAVY GROUND AEROSOL GENERATORS FOR THE CONTROL OF ADULT BITING INSECTS IN ALASKA[1]

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The usefulness of heavy ground equipment for generating aerosols for the control of adult *Culicoides,* mosquitoes, and blackflies was investigated under three types of Alaskan conditions during the summer of 1947. Tests were made in a small town with cross streets, in a small, wooded area encircled by roads, and in a third and more typical area traversed by a single road nearly 20 miles long. No unusual weather was encountered during the tests. Inversion or isothermic air temperatures occurred nearly every evening with few periods of strong breeze. Although little is known about the flight habits of these insects, there was probably little deviation from normal in the mild weather that prevailed during the tests.

The generators, a modified Besler (Chemical Corps designation E-15) and a large Hession, were mounted on a trailer towed by a ¾-ton truck. The Besler generator was operated at 600° F. and at a delivery rate of 40 gallons per hour. The Hession generator was a new machine of a type devised to produce a mist spray by throwing droplets from a set of rapidly revolving discs. The maximum flow rate was said to be 140 gallons per hour. The droplet size produced by both these generators was not determined.

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