

TESTS ON THE AIRPLANE APPLICATION OF DDT FOR THE CONTROL OF ADULT MOSQUITOES IN OPEN, UNWOODED AREAS

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Studies by members of the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine during 1943 demonstrated that satisfactory control of adult salt-marsh mosquitoes (*Aedes taeniorhynchus* [Wied.] and *A. sollicitans* [Walk.]) could be obtained by airplane applications of sprays containing DDT (1-trichloro-2, 2-bis [*p*-chlorophenyl] ethane) over dense mangrove jungles (Lindquist *et al.* 1). Later tests in conjunction with the United States Army showed that marked reductions in the populations of adult *Anopheles albimanus* Wied. and *Mansonia* spp. were possible in the tropical forests of Panama (Lindquist *et al.* 2). The tests herein reported were conducted in 1944 in the open, unwooded areas of east-central Arkansas against adults of *Anopheles quadrimaculatus* Say and *Psorophora* spp.

The large area of cultivated rice surrounding the Army Air Field near Stuttgart, Ark., was found to be highly favorable for the production of large populations of both *Anopheles* and *Psorophora* mosquitoes. Two series of tests were conducted in this area against the adult mosquitoes that were present during the period July 1 to September 4, 1944.

Methods.—The first series of tests was concerned with the control of adult mosquitoes within the breeding areas of the numerous rice fields in conjunction with

tests of DDT as a mosquito larvicide (Wisecup *et al.* 3). Observations were made in 14 fields on the effectiveness of such treatments in reducing the annoyance from *Psorophora* adults. Owing to the habit of *Anopheles quadrimaculatus* of leaving the rice fields, it had been found inadvisable to use nail-keg catching stations in such environments for determining populations of this species, but such stations were useful near locations where blood meals for mosquitoes were available, such as water holes and shady places where livestock gathered. It was found that enormous numbers of *Psorophora* spp. continued to remain in the rice fields, so that rather satisfactory estimations of the number present before and after treatment could be made from landing-rate counts.

The second series of tests was made in areas representative of forward, bivouac and cantonment areas, consisting of pastures, abandoned fields, and the cantonment area of the Stuttgart Army Air Field. The results of spraying such areas were evaluated by sampling the mosquito populations with the aid of light traps, nail-keg catching stations, and landing counts.

Three lots of material obtained from different sources were used, at dosages ranging from 0.1 to 1.0 pound of DDT per acre. Applications were made with 5 or 10 per cent strengths of emulsion or oil solutions. The emulsions were water dilutions of a basic concentrate consisting of 25 per cent of DDT, 7 per cent of *Triton X-100* (an alkyl polyether alcohol), and 68 per cent of xylene. The oil sprays consisted of DDT dissolved in No. 2 fuel oil (Diesel oil) with cyclohexanone added as an auxiliary solvent for the 10 per cent solution.

Most of the applications of DDT were made from liaison-type airplanes, with t

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removable spray unit designed at the Orlando laboratory for such airplanes. Swaths of 40-foot width were flown across the wind, starting on the leeward side of the area. In addition, a single large area was treated from a Stearman biplane, 80-foot swaths being made.

Results. Tests in Rice Fields.—The results of the tests made in the rice-field breeding areas are summarized in Table 1.

TABLE 1. Results of airplane treatments of rice fields with DDT emulsions for control of *Psorophora* adults.

Date of Application		Dosage of DDT per Acre	Area Treated	Control
1944		Pound	Acres	Per Cent
Lot 1 of DDT				
July	5	0.2	43	96
	6	.2	36	91
		.1	25	89
	11	.2	55	98
Lot 3 of DDT				
	11	.2	65	80
		.2	60	20
	15	.2	3	80 (90) ¹
	22	.2	16	93 (96)
Lot 2 of DDT				
		.4	36	90
	27	.4	20	94
	28	.8 ²	15	100
Aug.	4	.4	30	100
	11	.4	23	95
		.8 ²	30	100

¹ Figures in parenthesis refer to control in check plots treated with another lot of DDT.

² A 10-per cent DDT emulsion was used.

In all cases where marked reductions were noted in the number of mosquitoes following a treatment, it was also possible to find large numbers of dead adults floating in the water among the rice plants.

It was evident that the airplane application of 0.1 pound or more of DDT from lots 1 and 3 was effective in reducing the abundance of mosquitoes from annoying hordes to an occasional pest. The inferior results obtained with lot 2 were due to the application of minimum dosages of a material which was below standard both physically and chemically.

Area-Control Tests.—To gain information on the effect of DDT sprays on adult *Anopheles quadrimaculatus*, as well as on *Psorophora* spp., six tests were conducted whereby large, open, nonbreeding areas were treated.

A summary of these tests is presented in Table 2. This table shows the average counts of *Anopheles quadrimaculatus* per nail-peg catching station for about a week before the applications, both in the treated area and in a comparable untreated area; the average number of *Psorophora* spp. captured in portable light traps during the same period; and in certain tests the average landing rate per minute and the average number of *Psorophora* spp. captured in New Jersey light traps.

The application on July 11 was made to a square-mile area consisting of rice fields, pastures, farm lots, overgrown weedy rice fields of the preceding year, and an abandoned railroad right-of-way. Both the *Anopheles* and *Psorophora* populations were building up rapidly at this time, so that increases were shown in both the treated and untreated areas. The differences in the populations between these areas were insignificant, and it was apparent that the treatment had no bearing on the adult populations as registered by the methods of collecting which were employed.

The treatment on July 29 was applied to 300 acres of pasture, cultivated fields, and railroad right-of-way. The *Anopheles* population was still increasing at this time, as shown by the increases in both treated and untreated locations, but the *Psorophora* population had commenced a decline which later resulted in an almost complete absence of this usually abundant pest. There was an indication that the application had been somewhat effective against the anophelines, as the increase of this group in the treated area was only half that in the check area. The differences in catches of *Psorophora* between treated and untreated areas were again insignificant.

On August 7 an oil solution and a water emulsion of DDT were compared

TABLE 2. Summary of mosquito abundance in area-control tests, together with decrease or increase following treatment with DDT, as shown by nail-keg catches for *Anopheles quadrimaculatus* and light-trap catches for *Psorophora* spp. in open, nonbreeding areas.

Date	Dosage of DDT per Acre	Area Treated	Species	Plot	Mosquito Population Before Treatment	Decrease (—) Increase (+) Following Treatment			
1944	Pound	Acres			Number	Per Cent			
5 Per Cent Emulsion									
July 11	0.24	640	<i>A. quadrimaculatus</i>	Treated	3.6	—64			
				Untreated	25.2	—66			
29	.24	300	<i>Psorophora</i> spp.	Treated	1,816	+28			
				Untreated	1,594	+38			
			<i>A. quadrimaculatus</i>	Treated	13.6	+34			
				Untreated	13.2	+69			
			<i>Psorophora</i> spp.	Treated	3,598	—19			
				Untreated	2,104	—26			
Aug. 7	.24	28	<i>A. quadrimaculatus</i>	Treated	5	—32			
				Untreated	11.4	—95			
			<i>Psorophora</i> spp.	Treated	4,624	—59			
				Untreated	5,306	—50			
				Treated	13.5 ¹	—89 ¹			
				Untreated	16.2 ¹	—34 ¹			
5 Per Cent Fuel-Oil Solution									
Aug. 7	.24	28	<i>A. quadrimaculatus</i>	Treated	5.8	+32			
				Untreated	38.1	—25			
			<i>Psorophora</i> spp.	Treated	5,497	—80			
				Untreated	3,564	—86			
			<i>A. quadrimaculatus</i>	Treated	17.9 ¹	—93 ¹			
				Untreated	16.2 ¹	—34 ¹			
			25	.5	195	<i>A. quadrimaculatus</i>	Treated	12.2	—34
							Perimeter	21.3	+63
<i>Psorophora</i> spp.	Untreated	117.5				+44			
	Treated	1,032				—67			
Untreated	198	—46							
10 Per Cent Fuel-oil Solution									
Sept. 3	1.0	550	<i>A. quadrimaculatus</i>	Treated	104	—50			
				Untreated	88	—15			
			<i>Psorophora</i> spp.	Treated	163	—75			
				Untreated	258	—91			
				Treated	34.4 ²	—42 ²			
				Untreated	73.0 ²	—52 ²			

¹ Landing rates.

² New Jersey light traps.

in tests on a 56-acre pasture having a small stream, half the area receiving each treatment. Very contradictory results were obtained in these comparisons, possibly owing to the small areas employed. Decided decreases in the numbers of *Anopheles* were noted in both the treated and untreated portions of the plot to which the emulsion had been applied, but there was an increase in the oil-treated plot. The populations of *Psorophora* con-

tinued to show decreases during the period of checking, with nearly equal numbers in all areas, both treated and untreated shown in the light-trap collections. Marked differences in numbers of *Psorophora* between the treated and untreated plots were shown by the landing counts, the treated areas being almost entirely free of biting adults in the morning and at dusk.

As the mosquito populations had c

tinued large in the area treated on July 29, a second treatment was applied to the central 195 acres of this area on August 25, this time with DDT in fuel oil. The decided decrease in the number of *Anopheles* in the single nail keg placed in the center of the area, with increases in the stations around the perimeter and in the untreated areas, indicated that this treatment had been effective. There was a more marked decrease in the number of *Psorophora* within the plot than was noted outside.

The final test was made on the cantonment area of the Stuttgart Army Air Field with 10 per cent of DDT in fuel oil applied on September 3. A Stearman (PT-17) biplane equipped with a removable spray apparatus with venturi mounted under the fuselage was used on two-fifths of the area, and the same plane equipped with an apparatus to produce a finely dispersed spray from an engine exhaust generator was used on another two-fifths. A liaison-type plane (L-2) equipped with a removable spray apparatus with venturi mounted under the fuselage was used on the remaining one-fifth of the area. The different types of spray equipment were calibrated so that each applied approximately 1 pound of DDT per acre. As shown in Table 2, there was an over-all reduction of *Anopheles* amounting to 50 per cent, in contrast to a natural decrease of only 15 per cent outside the treated area. *Psorophora* populations had by this time decreased to the point where light-trap records were unreliable indices of their abundance.

Discussion.—In the course of these tests on the effects of spraying large, open non-breeding areas with DDT for the control of adult mosquitoes, it became evident that basic information was lacking on several factors that enter into such control. Too little was known concerning either the daytime or the nighttime habits of *Anopheles* and *Psorophora* adults. If the adult mosquitoes escape initial contact with the poison, there then remains the possibility of a later control by means of residues deposited on the foliage. Because of the

marked residual action shown by DDT under experimental conditions, a high degree of control under natural conditions can be hoped for, provided sufficient residue has been deposited in locations which the mosquitoes would subsequently contact long enough to obtain a lethal dose.

The main source of data on populations of pest mosquitoes of the genus *Psorophora* was catches in single light traps operated for several nights before and after treatment. These data demonstrated the tremendous variations in populations which were encountered during the season. By the last of August the numbers had decreased to only a fraction of those found during the peak of infestation. Less than a 25 per cent difference in the populations of adult mosquitoes as measured by light traps, however, was shown between the untreated and treated areas in all tests. It therefore seems probable that the use of light traps is an unsatisfactory method of determining *Psorophora* populations in areas of 1 square mile or less, owing to the habit of these mosquitoes of flying great distances and their known attraction to lights.

Despite the unsatisfactory evidence presented by light-trap collection, the few data obtained on landing rates and the very satisfactory results noted in tests against *Psorophora* adults in the rice fields warrant special emphasis. The landing-rate counts in the area treated on August 7 are indicative of the relief from these pests which was noted in many other instances. In both the treated areas daytime mosquito annoyance was negligible in comparison with that before treatment. Although there was a slight natural decrease in the untreated area, the difference between the treated and untreated portions of this pasture was evident for several days after treatment. The data obtained from these area-control tests indicate that early-morning and late-evening relief had been secured from the annoyance of pest mosquitoes, even though no actual decrease in nighttime numbers, as measured by light-trap collections, was shown. It appears that sufficient residue had been

deposited to control the nightly influx of mosquitoes from the surrounding area.

The data in Table 2 show very strikingly the tremendous changes in populations which took place within both treated and untreated plots during very short periods of time. It is probable that natural forces exerted greater influence on the results than did the treatments.

The general conclusion drawn from the data in Table 2 was that no appreciable control of *Anopheles quadrimaculatus* had been obtained from applications of DDT sprays at dosages from 0.2 to 1.0 pound of active ingredient per acre. There were indications, however, that the increase of these adults following the treatment on July 29 was much less in the treated area than in the untreated area. In the cantonment area it appeared that the decrease in the treated area was much greater than the natural decrease outside. Since increases were found in the stations around the perimeter and outside of the treated area, it is possible that the marked decrease at the station in the center of the 195-acre plot treated on August 25 was due to the treatment. The reductions were considered not to constitute control.

Summary.—Large-scale tests of the effectiveness of DDT in controlling adult *Anopheles* and *Psorophora* mosquitoes were conducted during the period May 25 to September 4, 1944, in the rice fields and pasture lands near Stuttgart, Ark.

Fourteen tests, involving over 450 acres of growing rice, made with liaison-type airplanes indicated that the abundance of *Psorophora* adults was reduced by at least 90 per cent when rice fields were sprayed with 0.1 pound or more of high-grade commercial DDT per acre in an aqueous emulsion. There were definite indications that 0.1 pound was a minimum dos-

age, and that inferior results were secured from the use of substandard materials.

Six area-control tests, involving several hundred acres of pasture and waste lands in large, open nonbreeding areas, indicated that:

(1) Techniques for determining adult mosquito populations should be improved.

(2) Treatments with either fuel oil or aqueous emulsion containing DDT at dosages of 0.2 to 1.0 pound per acre were of doubtful effectiveness against adults of *Anopheles quadrimaculatus* Say as measured by nail-keg catching stations.

(3) Light-trap collections of adult *Psorophora* spp. showed no marked differences between treated and untreated areas.

(4) Landing-rate counts of *Psorophora* spp. showed marked reduction of daytime annoyance from these mosquitoes in the treated areas.

(5) Apparently there is an extensive nighttime activity of adult mosquitoes of both *Psorophora* spp. and *Anopheles quadrimaculatus* under conditions of open, unwooded terrain, with a heavy breeding pressure from surrounding rice fields. Under such conditions light traps and catching stations are not suitable methods of evaluating differences in populations unless very large areas are to be treated

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