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REPORT ON A FIELD INVESTIGATION INTO THE EXTENT
AND DEGREE OF INSECTICIDE RESISTANCE IN A. gambiae IN THE AREA OF
THE WESTERN SOKOTO MALARIA PROJECT*

by

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The Western Sokoto Malaria Control Project started with a pilot scheme in which the area was divided into three zones and sprayed with DDT, BHC and dieldrin respectively.¹

The DDT zone was first sprayed in April 1954 and thereafter at six monthly intervals, all applications being at a dosage of 200 mgs per sq. ft.

The BHC zone was sprayed every six months from September 1954 to March 1956 when the period between sprays was cut to four months. All applications have been at a dosage of 25 mgs per sq. ft.

The dieldrin zone was sprayed at six monthly intervals from June 1954 to December 1955 at 25 mgs per sq. ft., but this dosage was doubled in the area between Birnin Kebbi and Ambursa in June 1955.

Physiological resistance to dieldrin in A. gambiae from Birnin Kebbi and Gwandu, towns situated at either end of the dieldrin zone was reported in November 1955.²

In April 1956, the area from Birnin Kebbi to Ambursa was sprayed with BHC at the high dosage of 40 mgs per sq. ft. The remainder of the zone with the exception of Gwandu was again sprayed with dieldrin, but at an increased dosage of 50 mgs per sq. ft.

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Between May and July 1956 the extension zone and Gwandu were sprayed with BHC, the dosage being 40 mgs per sq. ft.

A laboratory colony of dieldrin-resistant A. gambiae from Ambursa was established in London, the degree of resistance was measured and cross resistance to related hydrocarbons, including BHC was reported. The susceptibility to DDT of the dieldrin-resistant strain was the same as that of the susceptible colony strain from Lagos.³

Crossings between these resistant and susceptible strains have shown inheritance of dieldrin resistance to be monofactorial and a new technique for detecting resistance in the field has been suggested.⁴ This technique instead of comparing LC_{50} 's involves obtaining the whole LC_{100} for the local susceptible strain and selecting survivors of this dosage.⁴

The aims of this survey* were to investigate the extent and degree of insecticide resistance in the pilot project area, the possible spread of dieldrin resistance into the surrounding areas and the presence of cross resistance between the three insecticides in use.

Adult mosquitos were exposed to filter papers impregnated with risella oil solutions of insecticide according to the method of Busvine.⁵

All test material was taken to a central point for testing.

Two methods of obtaining material were used.

1. Hand catching of adults in houses

Where mosquitos were present in large numbers, collection by this method was relatively simple and gave a good sample of the population. However, in a sprayed area where resistance is not complete adults are likely to be scarce and it is possible that there is a pre-catch selection due to insecticide on the walls. Also the distance over which adults can be transported before testing is limited.

2. Larval collection

Breeding out of adults from wild-caught larvae is often possible where adults are scarce. There is no pre-catch selection and all adults can be exposed at the

* Performed during July-October 1956. Ed.

same age and the same stage of the gonotrophic cycle. Moreover larvae can be transported over somewhat longer distances than adults, but it should be borne in mind that any mortality occurring in transport may be selective.

Mosquitos from the dieldrin zone were exposed to a series of dosages between 0.5 per cent. and 4 per cent. dieldrin for one hour with no kill. A further series was exposed to 4 per cent. dieldrin for varying periods of time with the following results (Table 1).

Table 1.

Uncorrected per cent. mortalities for A. gambiae from Birnin Kebbi, Ambursa and Dagere exposed to 4 per cent. dieldrin in risella oil for varying periods of time

1 hour	2 hours	3 hours	5 hours	Check	18 hours	Check
2 (99)*	4 (73)	3 (39)	4 (77)	4 (45)	58 (51)	33 (24)

A. gambiae caught resting in houses at Diggi, an unsprayed village about 12 miles from Birnin Kebbi, were exposed to dieldrin, BHC, and DDT and the LC_{50} and the LC_{100} values for each insecticide were determined. The LC_{50} found at Diggi agreed with the results for homozygous susceptible material given by Davidson,³ i.e. all were killed by one hour's exposure to 0.5 per cent. dieldrin. Davidson also found that exposures of from one to five hours to 4 per cent. dieldrin did not kill homozygous resistant material, and after 18 hours he reported a kill of 70 per cent. Since the results shown in Table 1 are similar, 0.5 and 4 per cent. dieldrin were adopted as discriminating doses for determining the degree of dieldrin resistance.

Table 2, showing the proportions resistant in the pilot, the extension and the two unsprayed areas, brings out some startling facts. Not only is the level of resistance in the pilot zone extremely high, but that in the extension zone first sprayed only 2-3 months prior to this survey is equally high. Exposures at Diggi revealed the presence of potential resistance. Although the percentage was low,

* Numbers used for testing in brackets.

the high house densities (about 500 per house) would indicate that spraying with dieldrin might result in a high degree of resistance. At Sokoto, also unsprayed, an even higher proportion of the population was found to be heterozygous resistant.

Table 2

Degree of dieldrin resistance in sprayed and unsprayed zones

Zone	Proportion		
	Susceptible	Heterozygous resistant	Homozygous resistant
Pilot zone (excluding DDT)	9% (418)	2%	89% (805)
Extension zone	8% (72)	2%	90% (85)
Diggi (unsprayed)	99.96% (2666)	0.04%	0% (1336)
Sokoto (unsprayed)	94% (170)	6%	0% (102)

Table 3 shows that there is no relation between the house density and the level of resistance. Densities depend on a number of factors of which the time elapsed since the last spray seems to be only one.

Table 3

Place	Insecticide		Last sprayed	House densities		Per cent. resistant
	First spray	Last spray		Aug.	Sept.	
Kalgo	DLD* 25 mg	DLD 50 mg	April 1956	4	1.5	72 (50)
Birnin Kebbi	DLD 25 mg	BHC 40 mg	May 1956	21	20	95 (242)
Ambursa	DLD 25 mg	BHC 40 mg	May 1956	154	115	97 (201)
Dagere	DLD 25 mg	DLD 50 mg	May 1956	201	124	99 (79)
Gwandu	DLD 25 mg	BHC 40 mg	Aug. 1956	26	65	100 (26)
Jega	BHC 25 mg	BHC 25 mg	Aug. 1956	1	0.25	100 (29)
Aliero	BHC 25 mg	BHC 25 mg	Aug. 1956	4	3	91 (43)
Argungu/ Tiggi**		BHC 40 mg	May 1956	6	-	86 (42)

* DLD = dieldrin

** Argungu/Tiggi based on adults bred out from larvae only, all others from combined house catch larval collection figures.

Table 4 shows the degree of resistance found in all places from which adults and larvae were collected.

Table 4

Comparison of per cent. mortalities in A. gambiae collected in houses and bred from wild caught larvae

Exposed to dieldrin

Place	Dieldrin 0.5%			Dieldrin 4%		
	House catch	Bred from larvae	Combined	House catch	Bred from larvae	Combined
Birnin Kebbi	3 (128)	-	3 (128)	2 (97)	8 (145)	5 (242)
Gwadongwaje	0 (30)	5 (122)	4 (152)	2 (59)	14 (167)	11 (226)
Zauro	-	1 (108)	1 (108)	-	17 (110)	17 (110)
Ambursa	5 (21)	-	5 (21)	4 (135)	0 (66)	3 (201)
Kawara	16 (49)	7 (43)	12 (92)	-	10 (125)	10 (125)
Dagere	-	-	-	1 (72)	0 (7)	1 (79)
Gwaberen Fulani	25 (18)	7 (57)	17 (75)	40 (20)	10 (63)	22 (83)
Gwandu	0 (57)	-	0 (57)	0 (26)	-	0 (26)
Kalgo	-	27 (81)	27 (81)	-	28 (50)	28 (50)
Aliero	-	-	-	-	9 (43)	9 (43)
Jega	-	14 (7)	14 (7)	-	0 (29)	0 (29)
Gotomo	-	13 (38)	13 (38)	-	5 (43)	5 (43)
Argungu/Tiggi	65 (71)	3 (34)	44 (105)	0 (4)	14 (42)	13 (46)
Diggi	99.96 (2666)	-	99.96 (2666)	100 (1336)	-	100 (1336)
Sokoto	94 (122)	95 (48)	94 (170)	100 (83)	100 (19)	100 (102)

Table 5 shows that throughout the pilot zone dieldrin and BHC resistance are linked. In most cases the LC_{50} 's to BHC is higher than that found by Davidson.³ Although the LC_{50} 's for DDT in many of the dieldrin resistant towns is higher than that for Diggi, there does not appear to be any relation with dieldrin resistance.

Table 5

The LC_{50} 's of A. gambiae to DDT, BHC and dieldrin

Place	DDT	BHC	Dieldrin
Diggi	0.8	0.004	0.7
Sokoto	0.8	0.0032	0%*
Birnin Kebbi	1.4	0.42	95%*
Gwadongwaje	0.7	0.16	89%*
Zaure	1.1	c 0.13**	83%*
Ambursa	1.35	0.5**	90%*
Dagere	1.05	c 0.3**	99%*
Gwabaren Fulani	1.8	No test	78%*
Gwandu	1.3	0.5**	100%*
Kawara	0.85	0.52	90%*
Aliero	2.6	0.51	91%*

* LC_{50} 's to dieldrin not obtained, percentage surviving 4% dieldrin is shown.

** LC_{50} not obtained. Data based on two points only.

Tables 6 and 7 compare mortalities using wild caught and bred out material from the pilot project area exposed to BHC and DDT. The proportion of dieldrin and BHC resistant in the population is uniformly high throughout the area. Pre-catch selection in adults from sprayed houses does not appear to give a biased value when compared with results obtained from bred out adults. However a better log-probit regression line was obtained using bred out material.

Table 6

Comparison of per cent. mortalities in A. gambiae collected in houses
 and bred from wild caught larvae

Exposed to BHC

Collected from houses	0.025	0.05	0.1	0.2	0.5
Birnin Kebbi	0 (21)	0 (33)	3 (29)	17 (30)	58 (31)
Ambursa	-	1 (31)	0 (19)	1 (36)	-
Kawara	11 (9)	20 (10)	0 (15)	46 (13)	20 (10)
Dagere	4 (23)	17 (30)	17 (30)	18 (40)	-
Gwandu	-	0 (29)	3 (32)	2 (40)	-
Total	4 (53)	5 (133)	5 (125)	12 (159)	49 (41)
Bred from larvae					
Gwadongwaje	0 (28)	15 (27)	19 (27)	61 (26)	100 (19)
Zauro	0 (19)	21 (19)	18 (17)	80 (15)	100 (16)
Kawara	0 (16)	4 (25)	11 (41)	25 (32)	48 (27)
Aliero	0 (20)	0 (19)	5 (19)	16 (19)	50 (18)
Dagere	0 (10)	0 (8)	0 (10)	33 (9)	78 (9)
Gwandu	3 (36)	2 (40)	0 (37)	0 (39)	26 (38)
Total	1 (129)	7 (138)	9 (151)	30 (140)	58 (127)
Combined Totals	2 (182)	6 (271)	7 (276)	20 (299)	56 (168)

Table 7

Comparison of per cent. mortalities in A. gambiae collected in houses
 and bred from wild caught larvae

Exposed to DDT

Collected from houses	0.25	0.5	1.0	1.5	2.0	4.0
Birnin Kebbi	6 (63)	6 (72)	28 (68)	43 (76)	63 (75)	98 (69)
Ambursa	-	12 (18)	23 (18)	49 (23)	81 (22)	100 (116)
Dagere	-	0 (19)	47 (18)	75 (22)	87 (17)	100 (19)
Gwandu	-	11 (18)	21 (19)	50 (20)	79 (19)	-
Total	6 (63)	7 (127)	29 (123)	49 (143)	71 (133)	99 (104)
Bred from larvae						
Gwadongwaje	26 (15)	33 (54)	57 (65)	89 (57)	86 (66)	100 (60)
Zauro	-	16 (23)	28 (18)	79 (26)	82 (24)	-
Kawara	8 (39)	17 (35)	51 (41)	76 (29)	90 (30)	100 (27)
Dagere	0 (8)	0 (8)				
Gwabaren Fulani	4 (24)	0 (29)	12 (24)	13 (16)	50 (8)	92 (12)
Aliero	0 (19)	6 (17)	0 (21)	20 (20)	27 (18)	79 (24)
Total	8 (105)	17 (166)	39 (169)	66 (148)	77 (146)	95 (123)
Combined Totals	7 (168)	13 (293)	35 (292)	58 (291)	74 (279)	97 (227)

In the DDT zone along the dieldrin-DDT boundary, in the villages of Kardi, Gulumbe, Makangare and Kaurare, adult and larval collections were made. Except for Kardi no adults were found, and in Kardi the adults which were collected from an unsprayed Fulani hut, died before testing.

Within the DDT zone, Basabra, Shekaru and Yole after an extensive search failed to reveal either adults or larvae.

On the south-eastern border of the DDT zone, the villages of Tambawel and Melissa were searched for adults and larvae. No adults were found in either village, and the larvae that were reported breeding there were very few in numbers and confined to a small surface pool on the outskirts of Tambawel. From breeding sites along the Tambawel Melissa road, of the few larvae collected gambiae formed a very minor proportion.

It thus appears that well within the DDT zone, DDT is effectively controlling A. gambiae, and any gambiae found on the borders of the zone would suggest entry from adjoining areas.

The results of this survey showed that in all areas that have been sprayed with either dieldrin or BHC there was a high degree of dieldrin resistance with a linked BHC resistance.

The presence of a "resistance-potential" is indicated by the fact that in areas which have not been sprayed at all, a portion of the gambiae were heterozygous resistant. The phenomenally high speed with which resistant gambiae have established themselves in the sprayed areas confirms existence of the "resistance-potential".

Contrary to the views held by one of the authors, the survey revealed that there was no relationship between the degree of resistance and the density of mosquitos in sprayed areas.

The high LC_{50} 's to DDT in the project area can be attributed to an increased vigour of the resistant mosquitos.

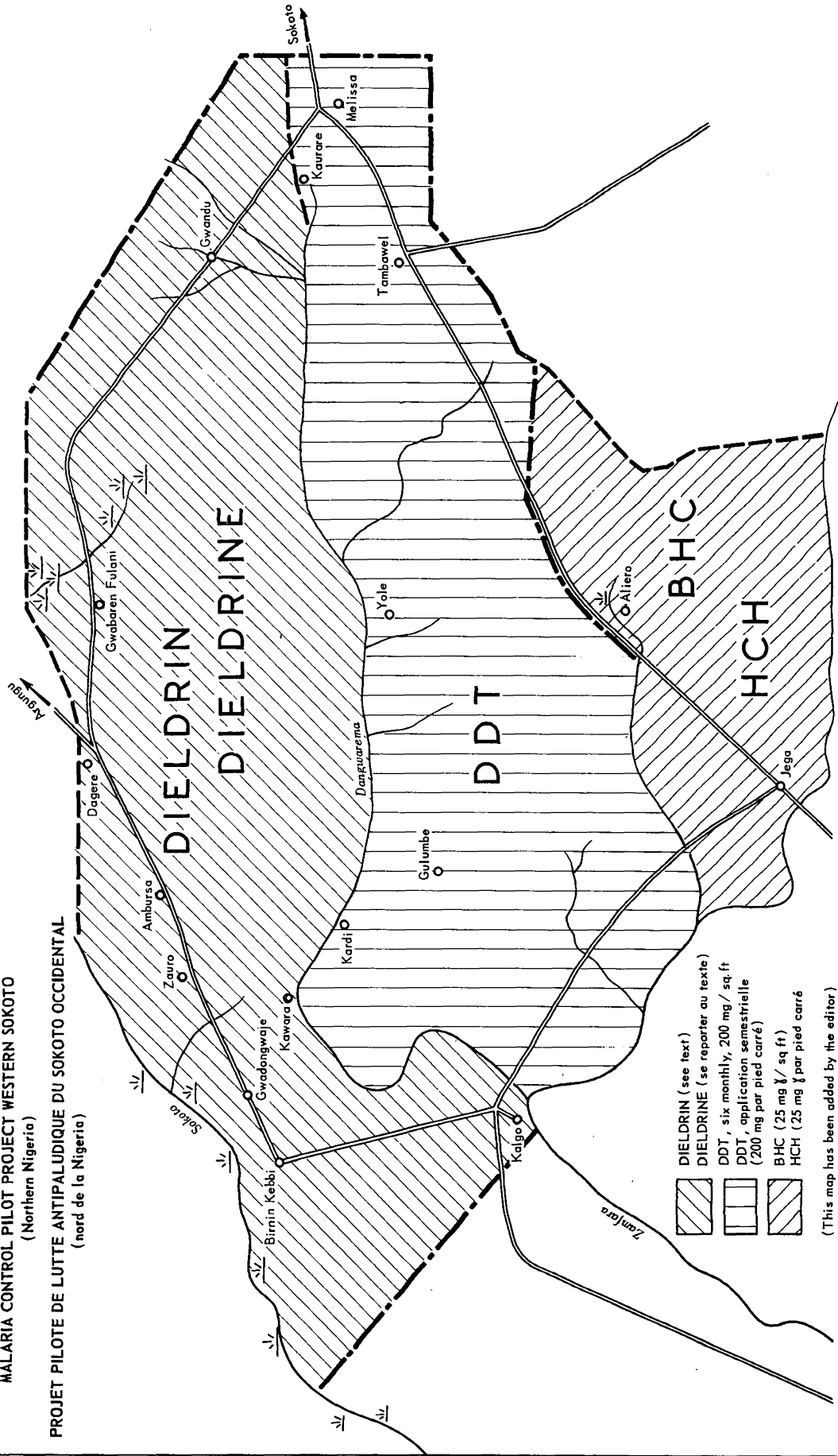
It appears that DDT is the best of the three insecticides in use, in that neither adults nor larvae of A. gambiae were collected from within the DDT zone.







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MALARIA CONTROL PILOT PROJECT WESTERN SOKOTO
(Northern Nigeria)
PROJET PILOTE DE LUTTE ANTIPALUDIQUE DU SOKOTO OCCIDENTAL
(nord de la Nigeria)



-  DIELDRIIN (see text)
-  DIELDRIINE (see reporter au texte)
-  DDT, six monthly, 200 mg / sq. ft
-  DDT, application semestrielle (200 mg par pied carré)
-  BHC (25 mg $\frac{1}{2}$ / sq ft)
-  HCH (25 mg $\frac{1}{2}$ par pied carré)

(This map has been added by the editor)
(La présente carte a été ajoutée par l'éditeur)