UNITED NATIONS | NATIONS UNIES

WORLD HEALTH ORGANIZATION | ORGANISATION MONDIALE DE LA SANTÉ

CONFERENCE ON MALARIA IN AFRICA

WHO/Mal/158
Lagos Conf./30
15 February 1956

ORIGINAL: ENGLISH

INSECTICIDE RESISTANCE IN WESTERN SOKOTO

by

R. ELLIOTT
Entomologist, Malaria Service,
Department of Medical Services, Federation of Nigeria

and

V. RAMAKRISHNA
Entomologist, WHO
(Attached to the Western Sokoto Malaria Control Pilot Project)

1. INTRODUCTION

This paper is to be regarded as an interim report on work which, while at present far from complete, appears to be of sufficient importance in its implications to justify being made known to other workers in the field at an early stage.

The Western Sokoto Malaria Control Pilot Project is a residual spraying scheme covering an area of 600 square miles of territory in the Sudan savannah region of northern Nigeria, in which a population of 120,000 is to be protected. The area is divided into three zones; in one, amounting to half the total, dieldrin is used; in two thirds of the remainder, DDT is used, while BHC is employed in the smallest zone. The dosage and application periods were:

(i) DDT at 200 mg/sq.ft (2 g/m^2) in April to June 1954
September to November 1954
April to June 1955

(ii) (a) Dieldrin at 25 mg/sq.ft (250 mg/m^2) in June to August 1954
November 1954 to February 1955

(b) Dieldrin at 50 mg/sq.ft (0.5 mg/m^2) was used over half of the dieldrin zone in June to August 1955

(iii) BHC at 25 mg/sq.ft gamma isomer (250 mg/m^2) in August to September 1954
February to March 1955
August to September 1955

2. METHOD AND RESULTS

2.1 House-flies

It was a matter of common observation that the flies in the Project Area which had responded with a great reduction in numbers to the first spraying, had since recovered and became as great a pest as before. It was therefore decided to find out if they present any degree of resistance to insecticides generally and especially to dieldrin which is the toxicant used over half of the total area of the Project.

Two colonies of flies, one from Birnin Kebbi in the dieldrin zone and one from Argungu, a town in the unsprayed check-zone about 15 miles outside the sprayed area, were brought from Western Sokoto and established at Yaba.

The flies from Birnin Kebbi in the dieldrin zone were found to be of normal Musca domestica vicina type, the males having the narrow vertex typical of the sub-species. Those from Argungu in the unsprayed zone were, however, even narrower in the vertex, approaching the M. nebulo or M. cuthbertsoni type. The two strains were found to be able to interbreed freely, as had previously been demonstrated by Sacco (1951) for the three types M. domestica, vicina and nebulo. It is therefore probable that these variable and plastic tropical house-flies constitute a species complex within which interchange of genetic material, including factors concerned in insecticide resistance, takes place.

The flies were transported as larvae and pupae found breeding in semi-composted town refuse and night soil and the investigations were carried out on the first and second generations of descendants of these wild caught individuals maintained under standard laboratory conditions. The conditions were those described by Busvine and Harrison (1953) except that the larval pabulum was autoclaved before use. The flies were tested for sensitivity to

DDT, dieldrin, BHC, malathion, and parathion. Malathion was included since it has been suggested as an insecticide of choice against DDT-resistant flies. The method of testing was that of topical application of micro-drops of the toxicant used by Busvine (1951).

The results of this investigation are shown in Tables 1, 2 and 3 below.

Table 1

Mortality of houseflies from the treated and untreated zones of W. Sokoto after the topical application: 0.4 mm^3 of oil solution applied to the dorsum of thorax

Toxicant	Concentration %	Birnin Kebbi				Argungu			
		Females		Males		Females		Males	
		No. exposed	Per cent. mortality	No. exposed	Per cent. mortality	No. exposed	Per cent. mortality	No. exposed	Per cent. mortality
Dieldrin	4	44	88	42	98	10	100	-	-
	2	57	58	49	90	10	90	20	100
	1	73	45	69	64	20	80	20	95
	0.5	69	25	74	47	35	77	20	85
	0.2	30	3	30	6	35	57	28	68
	0.1	20	0	20	0	17	41	27	52
DDT	2	11	90	18	100	10	100	10	100
	1	39	62	35	88	10	100	10	100
	0.5	62	49	72	75	30	97	20	100
	0.2	53	34	41	46	25	60	25	92
	0.1	35	17	35	29	25	48	25	52
	0.05	15	0	15	0	20	20	20	45
Gamma BHC	0.2	49	81	48	95	10	90	10	100
	0.1	51	33	53	75	30	70	30	83
	0.05	20	10	20	40	30	40	20	60
	0.02	40	2	40	32	46	20	40	55
	0.01	20	0	15	0	15	13	10	20
Malathion	1	20	100	20	100	10	100	10	100
	0.5	20	100	20	100	10	100	10	100
	0.2	20	80	20	100	10	100	10	100
	0.1	20	25	20	70	10	80	10	100
	0.05	10	10	25	40	30	37	17	70
	0.02	-	-	20	25	15	23	15	26
	0.01	-	-	16	18	15	13	15	13

Tables 2 and 3 show the median lethal concentrations of various insecticides to houseflies from Birnin Kebbi and from other parts of the world.

Table 2

Median lethal concentrations of various insecticides to houseflies from Birnin Kebbi and Argungu (showing the apparent increase in resistance)

Toxicant	Median lethal concentration (per cent.)					
	Females			Males		
	Argungu	Birnin Kebbi	Increase	Argungu	Birnin Kebbi	Increase
Dieldrin	0.18	1.3	x 7.2	0.1	0.65	x 6.5
DDT	0.13	0.45	x 3.5	0.1	0.23	x 2.3
Gamma BHC	0.06	0.12	x 2	0.26	0.06	x 4.3
Malathion	0.05	0.15	x 3	0.33	0.66	x 2

Table 3

Median lethal concentrations of various insecticides to different strains of houseflies (partly after Busvine 1954)

Fly Strain (Females)	Median lethal concentration (per cent.)		
	Dieldrin	DDT	BHC
Uruguay*	3.0	0.35	0.8
Omdurman*	1.5	0.6	0.5
Birnin Kebbi	1.3	0.45	0.12
Argungu	0.18	0.13	0.06
Laboratory*	0.005	0.08	0.008

* Busvine 1954

2.2 Anopheles gambiae

The fact that in spite of a very impressive (over 98 per cent.) reduction of the room density indices for A. gambiae in treated zones of the Project Area a small proportion of mosquitos continued to appear at the peak of the rainy season of 1955 led to the investigation of a possible phenomenon of resistance to residual insecticides and particularly to dieldrin used over the greater part of the project.

The A. gambiae Giles from the Western Sokoto area appear to be in all respects typical members of the species. They were, being of wild origin, larger than the colony-bred material worked on by Busvine and others in London, and are certainly larger than the average of the Malaria Service colony at Yaba. The size difference is in no way sufficient to account for the difference in susceptibility, as the pick-up of toxicant from oil-treated filter papers is likely to be in proportion to the size of the insect.

Attempts were made by one of the authors (R.E.) in September 1954 to carry out the WHO sensitivity test, based on the methods of Busvine and Nash (1953). These were unsuccessful due to high control mortalities caused by the necessity of transporting wild caught adult mosquitos to the laboratory. In September 1955 a new insectary was completed at the headquarters of the Project and with its use a fair supply of viable adult A. gambiae became available for experiments. These were bred from larvae and pupae collected in the field, at first in the dieldrin zone, and later from elsewhere. Blood-fed adults were handled with an aspirator, and were otherwise treated as recommended by Busvine and Nash (1953).

They were exposed in batches of four or five for one hour on filter paper treated with solutions of insecticides in Risella oil, and after 24 hours examined for death or recovery. In some trials wild-caught adults were used in place of the laboratory-reared material.

The results of the first trials in July 1955 had suggested that some degree of resistance to both DDT and dieldrin was present in A. gambiae from the dieldrin treated zone.

The results of the two series of tests on mosquitos carried out during September-October 1955 are shown in Table 4.

Table 4

Resistance tests using DDT and Dieldrin on blood-fed A. gambiae

Place	Type of Material	Toxicant	Concentration per cent.	Number exposed	Per cent. mortality
Birnin Kebbi (Dieldrin zone)	Hatched out	Dieldrin	4 2 1 0.5	64 62 70 61	83 45 16 5
Owandu (Dieldrin zone)	Wild caught	Dieldrin	4 2 1 0.5	15 15 15 15	93 60 33 20
Birnin Kebbi (Dieldrin zone)	Hatched out	DDT	4 2 1.6 1.3 1 0.5	15 25 16 16 20 11	100 92 31 6 5 0
Argungu (Unsprayed zone)	Wild caught	Dieldrin	4 2 1 0.5	35 35 36 14	100 ø 100 ø 100 ø 100 +

ø 100 per cent. K-D in one hour

* 57 per cent. K-D in one hour

Median lethal concentration for A. gambiae from the dieldrin zone:

Dieldrin 2 per cent.)
) (this is only a rough calculation)
DDT 1.6 per cent.)

3. DISCUSSION

The results on mosquitos indicate that the use of dieldrin for 18 months has given rise to a strain of A. gambiae with an increased specific resistance to that toxicant coupled with an evident though less marked resistance to DDT. The failure to demonstrate the absence of this resistance in mosquitos of the Pilot Project before spraying began is unfortunate, but the continued presence of highly susceptible members of the species at Argungu in unsprayed territory only 15 miles outside the sprayed zone suggests that the above statement is substantially correct.

It is suggested that the evidence of the resistance in flies is relevant, although there is nothing unexpected in the emergence of a resistant strain of the housefly. The most interesting feature is probably the pattern in which resistance has developed. The work of Busvine and co-workers (1951, 1953, 1954, and 1955) has tended to show that in flies exposed to combinations of DDT and BHC, or of DDT and chlordane in the field, two distinct types of resistance appear, one mechanism protecting against DDT, while another, developed by exposure to BHC or chlordane, protects against both BHC and the Diels-Alder group of insecticides. Thus flies of diverse origin, exposed to the combinations mentioned, have developed resistance to compounds never used against them in the field, such as aldrin and dieldrin. The explanation offered is based on certain resemblances in the molecular structure of gamma BHC, chlordane, aldrin, dieldrin, endrin and isodrin. The resemblance is not shared with DDT, to which the flies are not, relatively to normal flies, so resistant as they are to the other group.

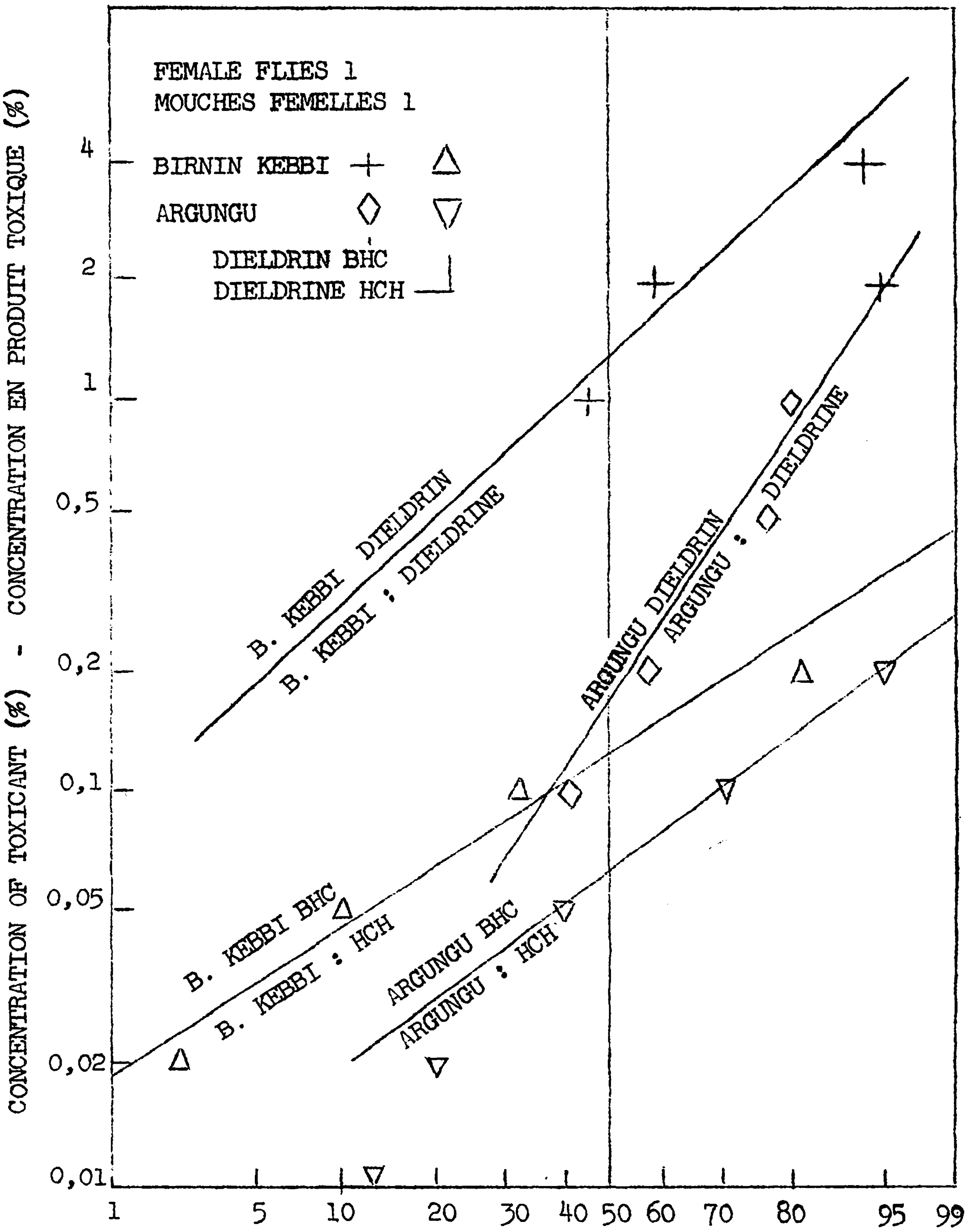
The present case shows a rather different pattern. Exposure to dieldrin only has raised resistance to dieldrin as compared to the flies from Argungu, seven times; resistance to DDT and BHC has also been raised, threefold and twofold. But resistance to the totally unrelated compound malathion has also been raised threefold. Comparison with Busvine's (1954) results on strains from Uruguay and Omdurman shows that the Birnin Kebbi flies have not acquired so much resistance as these highly resistant insects, even to dieldrin. Both cases seem to indicate a raising of the level of tolerance, not only to the insecticide to which the flies have been exposed in the field (DDT and BHC in the case of the Uruguay and Omdurman strains) but also to toxicants in general. The fact that exposure to DDT and BHC has resulted in Busvine's strains having an even greater resistance to dieldrin, which they had not met in the field, than to the toxicants they had met is extremely hard to explain on any theory not based on a common mechanism for resistance to the chlorinated group as a whole. If resistance to chlorinated hydrocarbons is also associated with resistance to compounds such as malathion (O,O-dimethyl dithiophosphate of diethyl mercaptosuccinate) some more general type of mechanism must be present as well as specific resistance to related groups of toxicants.

It will be noted that the Argungu strain is notably more resistant to all three insecticides than the non-resistant laboratory strain of M. domestica used by Busvine (1954). This may be accounted for either by a naturally-occurring tolerance or by the overspill of genetic material from the treated area of Western Sokoto. Earlier investigations on Nigerian houseflies (Busvine and Harrison 1953) show median lethal concentrations little different from those for non-resistant English flies except in the case of M. vicina from Ilaro, where an acquired resistance to BHC was demonstrated. It seems possible, therefore, that resistant genes, once they become widespread in a population, may diffuse outside the area in which the conditions favouring their increase exist. The significance of this, where control operations are being expanded by annual increments, is that in the later stages resistance may be expected to be present from the outset due to the genes for resistance having spread in the population in advance of the spread of insecticide treatment.

References

Busvine, J. R. (1951) Nature, 168, 193-195
Busvine, J. R. (1953) Nature, 171, 118-119
Busvine, J. R. & Nash, R. (1953) Bull. ent. Res. 44, 371-376
Busvine, J. R. & Harrison, M. (1953) Bull. ent. Res. 44, 729-738
Busvine, J. R. (1954) Nature, 174, 783-785
Busvine, J. R. (1955) Trans. roy. Soc. trop. Med. Hyg. 49, 483-487
Sacca, G. (1953) Riv. Parassit. 14, 97

FIG. 1



PERCENTAGE MORTALITY (PROBABILITY SCALE)

MORTALITE EN POURCENTAGES (ECHELLE DE PROBABILITE)

FIG. 2

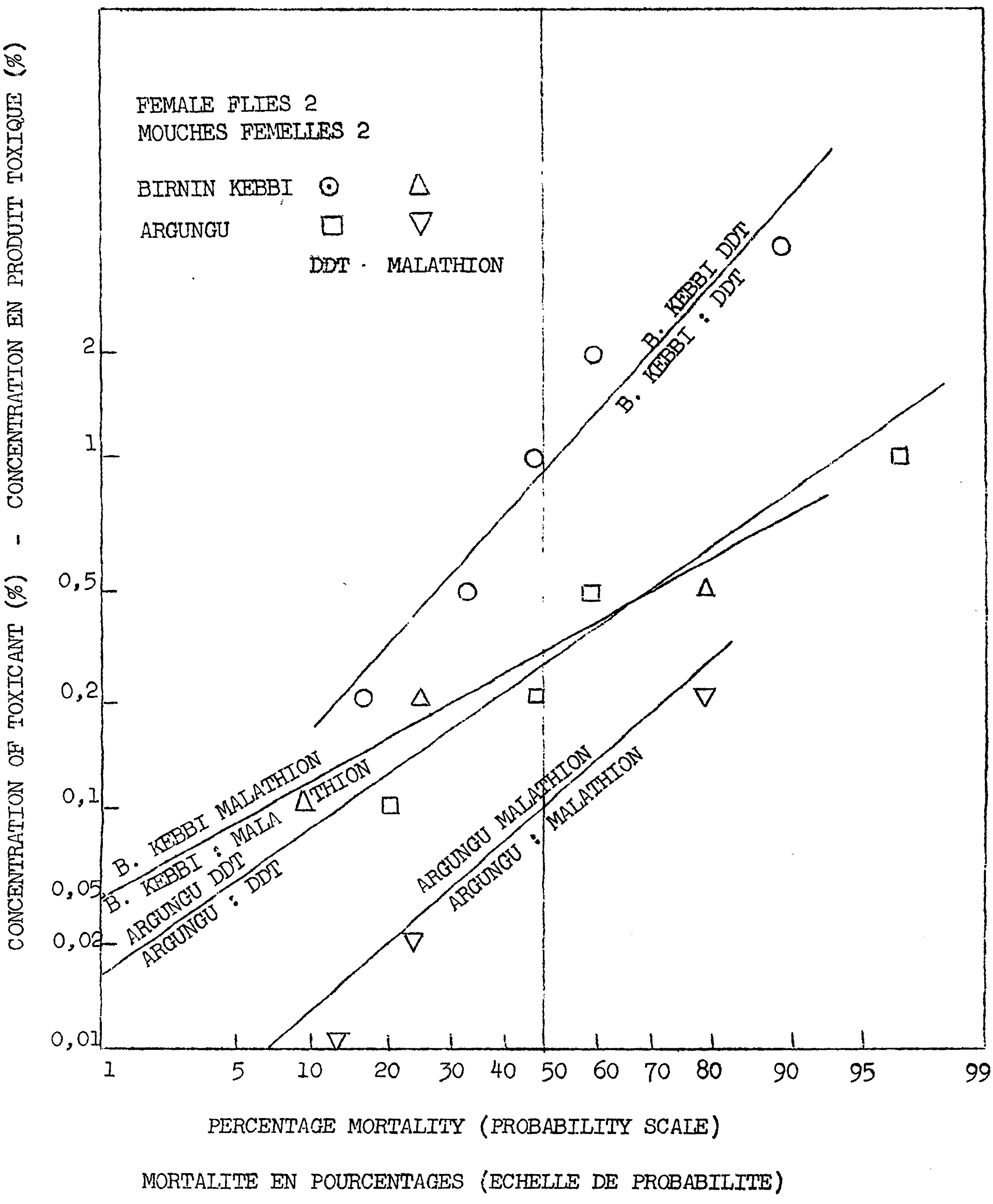

FEMALE FLIES 2
MOUCHES FEMELLES 2
BIRNIN KEBBI
ARGUNGU
DDT · MALATHION
B. KEBBI DDT
B. KEBBI : DDT
B. KEBBI MALATHION
B. KEBBI : MALATHION
ARGUNGU DDT
ARGUNGU : DDT
ARGUNGU MALATHION
ARGUNGU : MALATHION
CONCENTRATION OF TOXICANT (%) - CONCENTRATION EN PRODUIT TOXIQUE (%)
2
1
0,5
0,2
0,1
0,05
0,02
0,01
1
5
10
20
30
40
50
60
70
80
90
95
99
PERCENTAGE MORTALITY (PROBABILITY SCALE)
MORTALITE EN POURCENTAGES (ECHELLE DE PROBABILITE)

FIG. 3

RELATIVE RESISTANCE TO INSECTICIDES OF WESTERN SOKOTO HOUSEFLIES

RESISTANCE COMPARATIVE DE MOUCHES DOMESTIQUES DU SOKOTO OCCIDENTAL
A DIVERS INSECTICIDES

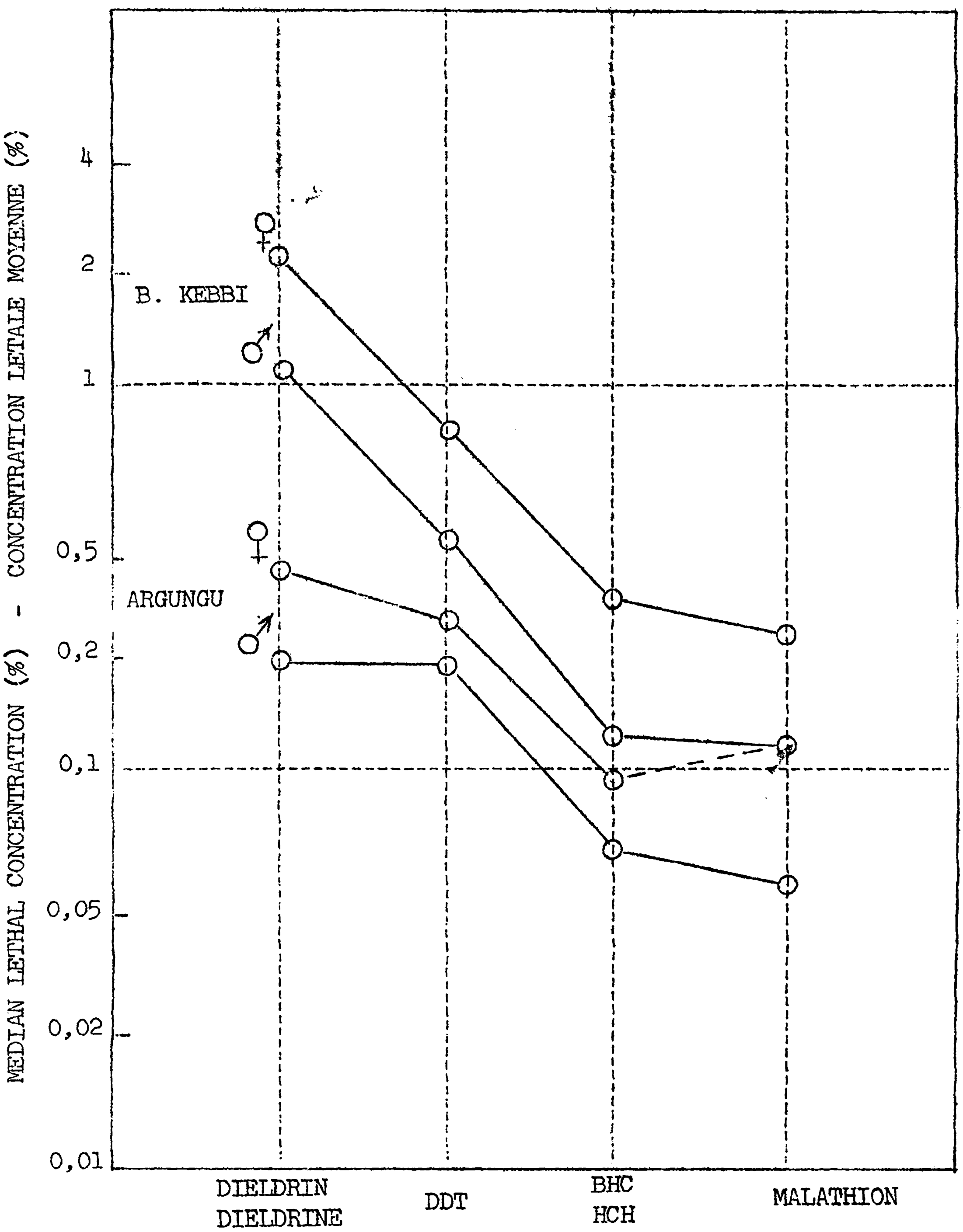


FIG. 4

RELATIVE RESISTANCE OF HOUSE FLIES TO INSECTICIDES
(Partly after Busvine, 1953-1954)

RESISTANCE COMPARATIVE DE CERTAINES MOUCHES DOMESTIQUES A DIVERS INSECTICIDES
(Données tirées en partie des travaux de Busvine, 1953-1954)

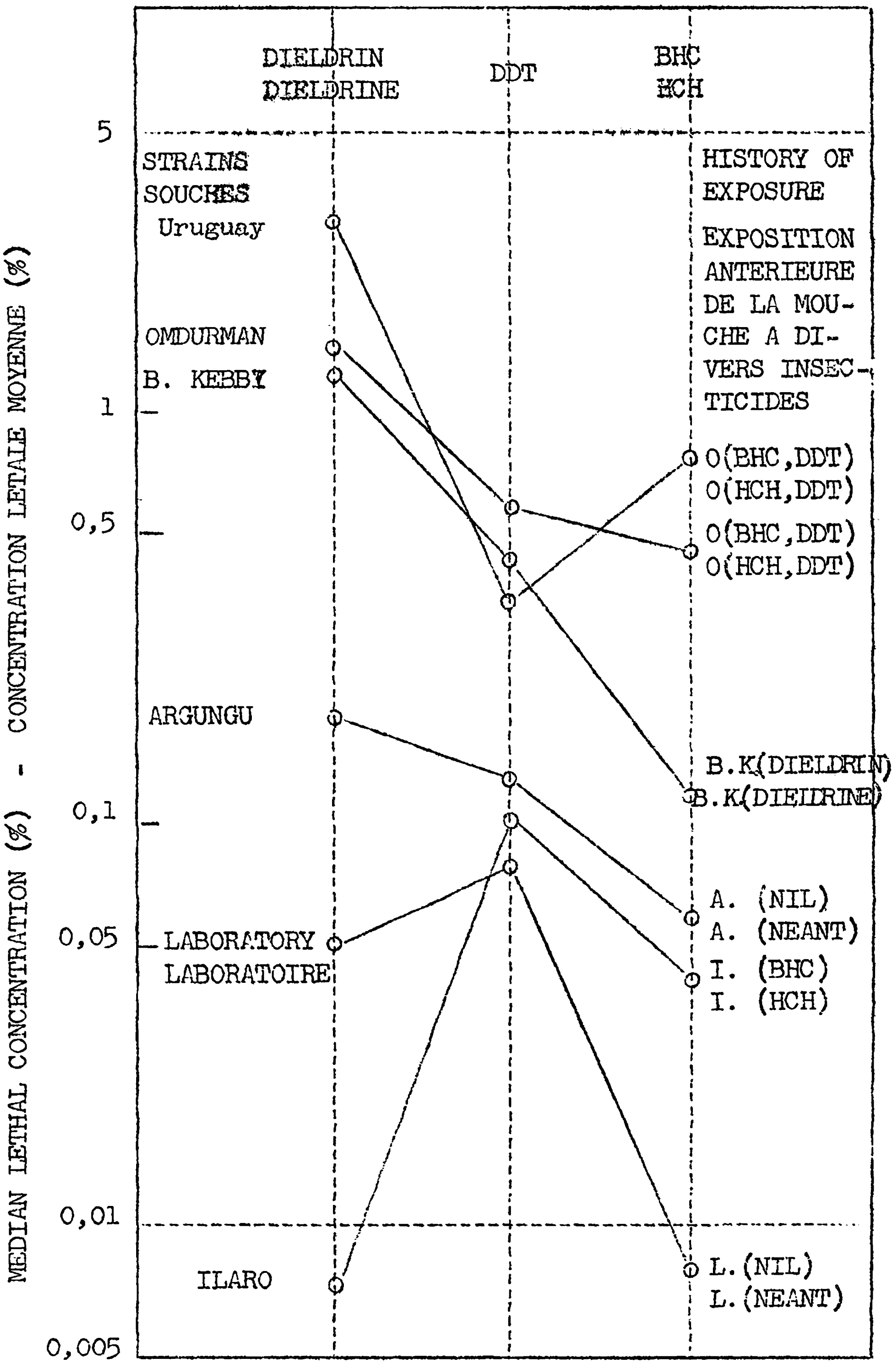
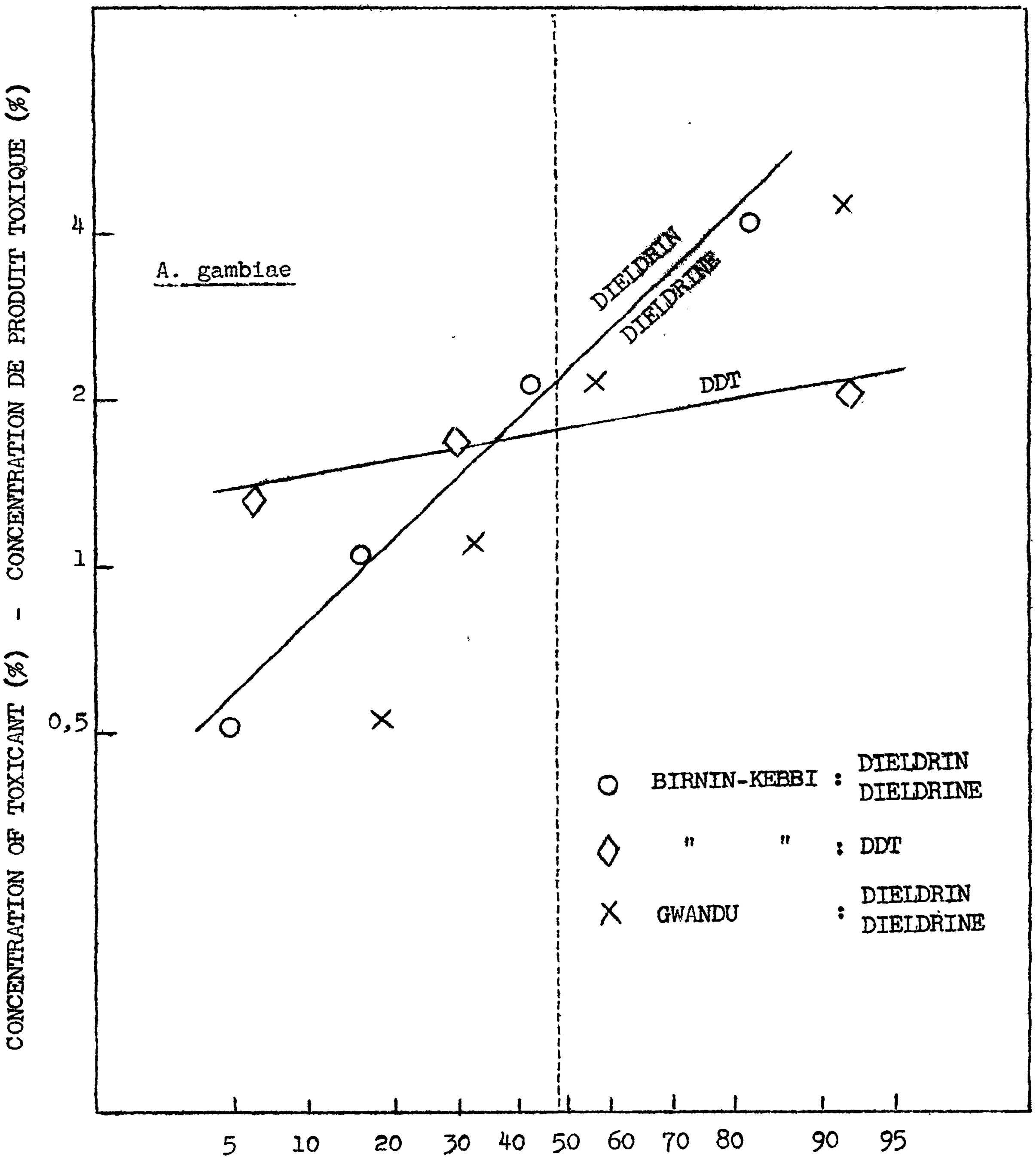


FIG. 5



PERCENTAGE MORTALITY (PROBABILITY SCALE)

MORTALITE EN POURCENTAGES (ECHELLE DE PROBABILITE)