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SUMMARY OF OCCURRENCES OF INSECTICIDE RESISTANCE IN ANOPHELINE MOSQUITOS (ALL REGIONS) AND OF RESULTS OF SUSCEPTIBILITY TESTS BY THE WHO METHOD IN THE AMERICAS[1]

WHO Headquarters has so far issued three compilations of the results of tests for susceptibility to insecticides in anopheline mosquitos. Two were of tests on adult mosquitos, viz. document WHO/Mal/189 - WHO/Insecticides/63 (June 1957), later published in Bull. Wld Hlth Org. 16, 874-890 (1957); and document WHO/Mal/203 - WHO/Insecticides/77 (April 1958). The third was of tests on larvae, viz. WHO/Mal/199 - WHO/Insecticides/74 (February 1958). In these documents the test results received were set out in full. The adult tests were carried out for the most part following the method of Busvine and Nash. For the larval tests no standard method was consistently used.

Between April 1958 and April 1959 the volume of tests performed on adult anophelines and reported to WHO has increased rapidly, whereas the number of tests on larvae remains small. The great majority of investigators now use the standard WHO test kits (adult and larval kits), which for brevity are called the WHO method. Detailed instructions accompany every kit sent out.

Because of the much greater volume of results it is now found necessary to change the form of compilation. Probably few readers would be interested in details of the mortalities obtained at each concentration of insecticide. Most will wish to see at a glance what conclusions may be drawn from the tests. Furthermore, it seems desirable to present side by side all the data relating a local population of a vector species to both DDT and dieldrin. The form of compilation adopted here allows this to be done.

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[1] Prepared by the Division of Malaria Eradication, WHO HQ, Geneva.

Owing to pressure of work it has been found necessary to assess and summarize these test results region by region. The present document gives the reader an up-to-date survey of all the instances of insecticide resistance in anopheles so far confirmed from any part of the world, followed by a summary of information from susceptibility tests received from the Americas. Tests included in the earlier documents are not repeated in this summary. It is our aim to present similar summaries from each of the other regions during 1959.

Insecticide Resistance in Anophelines

Within the past twelve months the number of anopheline species shown to be capable in the wild state of developing resistance to chlorinated hydrocarbon insecticides has grown from six (see WHO/Mal/203) to seventeen. They are listed in Table 1. Two species have been found resistant to DDT only, four to DDT and dieldrin, and eleven to dieldrin only. Most of the species tested and confirmed as resistant are known to be important vectors of malaria. In a few cases (e.g. A. fluviatilis in Saudi Arabia) the resistance has occurred in a country other than that where the species is a confirmed vector; and the role as vectors of a few resistant species (e.g. A. annularis, A. vagus) is doubtful.

The most immediate problem from the point of view of vector control arises where a vector is resistant to both DDT and dieldrin in the same area. Fortunately this is not the case in A. subpictus subpictus, for whereas the resistance of this sub-species to dieldrin occurs in Java its resistance to DDT is found at the opposite end of its range, in Nepal and a small area of India.

Again, the DDT-resistance found in A. quadrimaculatus in the United States of America was limited to the larvae, whose LC_{50} was 20 times or more that of a susceptible population. Brown (1958) concluded, from all the available evidence, that A. quadrimaculatus can develop very little DDT-tolerance, if any, in the adult stage. On the other hand the dieldrin-resistance of this species in Mississippi, though apparently produced by contamination of the breeding places, is exhibited by both the larval and the adult stages.

In A. sacharovi the phenomenon of dual resistance has been recognized in Greece since 1954. Nevertheless, DDT is regarded by the National Malaria Service of Greece as still a useful insecticide against the vector, for where the need is to stop transmission in localized residual foci of malaria a prompt application of DDT, combined with the use of drugs, is often found sufficient. This may be due on the one hand to the fact that A. sacharovi is no longer as resistant as formerly, in areas where there has been no spraying for several years, and secondly, to the action of the insecticide in driving the mosquitos out of doors, where they may be less likely to survive or to bite man.

The problem of imagocidal measures is especially acute in those areas of Central America where A. albimanus exhibits dual resistance. As in a number of other cases (A. gambiae in Nigeria, A. sacharovi in Greece and Turkey) resistance appears to be most marked, and to develop most rapidly where there are cotton crops liberally treated with DDT/BHC dust. It was first confirmed in El Salvador in July 1958 and has since been found in four other countries, most recently at Belize, British Honduras. An active search is now under way in Central America for an alternative insecticide to control A. albimanus.

Table 1 lists the instances of physiological resistance only. Some instances have been reported of an heritable change of normal resting place, produced by selection pressure from a residual insecticide sprayed in houses. This is a phenomenon we have at present no reliable means of measuring.

Measurements have recently been made, however, of another type of behaviouristic change: developed hyper-irritability. DDT probably has an irritant effect on all anophelines. In a susceptible population the individuals most quickly irritated will be the ones most likely to escape lethal intoxication. Selection can occur, therefore, of strains exhibiting increased irritability to DDT. The development of such hyper-irritable strains of Anopheles has been shown during 1958 in A. albimanus (by Brown in Panama) and in A. sacharovi (by de Zulueta, in Greece). Each of these workers used as a measure of irritability the incidence of take-off by mosquitos resting on known concentrations of DDT in Risella oil.

DDT in houses will naturally tend to drive irritated mosquitos to seek other resting places. Thus the collectors may find them resting exclusively in outdoor or other unsprayed shelters, although they have developed no inherent preference for such resting places, and do not exhibit the inherited change of resting habit mentioned above. A mosquito showing changes in its chosen resting places will be likely, if still anthropophilic, to continue transmitting malaria. One that is driven from the houses by DDT irritation, on the other hand, may cease to be a vector by reason of the increased hazards it encounters out of doors, provided that all indoor shelters have been well sprayed. We have suggested the possibility that this happens to A. sacharovi in Greece.

Regional Summary of Susceptibility Tests - I: The Americas (Table 2)

In the earlier assessments the LC_{50} value was used as the only yardstick of susceptibility. This value is a logical expression of the relationship between an insect population and an insecticide only where the population is genetically homogeneous in its response to the insecticide and where variations in individual tolerance are due to normal variability. Where, on the other hand, there exists an hereditary factor conferring ability to tolerate the insecticide, the specimens possessing this factor fit one dosage-mortality curve and those lacking it fit another. The LC_{50}, applied to such a mixed population, may be wholly misleading and in any case, provides no accurate index of the susceptibility of the population as a whole.

The LC_{50} value was sometimes based, in the past, on a single unreplicated test. This might include as few as ten mosquitos exposed to each concentration of the insecticide. If the mortalities obtained were all above, or all below 50% the value would be read graphically by extrapolation. This procedure might be grossly misleading. In preparing the present summary the practice of extrapolating upwards from the highest concentration in the kit has been discontinued, on the supposition that populations showing a top kill of less than 50% are almost certainly heterogeneous.

A rather large number of tests has had to be excluded from the present summary on account of inadequacies of one kind or another. The commonest weaknesses were: lack of replicates, too few mosquitos exposed to each concentration, too few concentrations included in the test, and excessive mortality in the controls. Comparison of the criteria adopted for tests included in the summary, with the instructions issued with the WHO kits, will show that it has unfortunately been necessary frequently to relax the insistence on strict attention to the instructions. Obedience to these is, nevertheless, the minimal basis for obtaining scientifically valid results, and WHO will continue to ask entomologists to make every effort to carry out susceptibility tests in conformity with the instructions in future.

Criteria for Including Tests in the present Summary (Table 1)

1. Range of concentrations

(a) the full range to be used whenever a population was first tested. If the preliminary test showed that susceptibility was very high or very low, replicate tests were accepted in which were used only the three lowest or the three highest concentrations, respectively;

(b) in routine checks on the continued susceptibility of a population, the lowest concentration expected to give 100% mortality might be used alone (on three or more batches).

(c) in checks to measure any increase in the proportion of resistant specimens, tests on at least 50, and preferably 100, specimens, at the lowest concentration known to kill all susceptible specimens; also (numbers permitting) tests at the next concentration above this.

2. Number of female mosquitos per tube: 16 - 25.

3. Exposure time: one hour. (But in addition, 2, 4, 8 or 16 hours where the investigator, having recognized resistance, aimed to establish the order of exposure lethal to the resistant specimens).

4. Number of replicates: at least two. (The results on a given concentration are ignored if the total number of mosquitos exposed to it was below 40 - compare the instructions, where resistance is placed upon four replicates with 20-25 mosquitos in each batch).

5. Control mortality: 15% or under in any one test; 10% or under when averaged over a series of replicates.

6. Comparability of replicates: tests are regarded as replicates when they are performed under similar conditions, at the same place, within a period of 15 days.

7. Calculation of LC_{50}: where a definite value is stated this means either that average partial mortalities both above and below 50% were obtained, or that one concentration gave an average mortality of between 50% and 65%; further, that it was possible to draw a well-fitting, straight dosage-mortality line up to at least the 95% mortality level. In other cases the figure for the LC_{50} is preceded by the sign <or >. The "basis" number, placed in brackets after the LC_{50} value, is the total number of mosquitos exposed to all concentrations which gave partial average rates of mortality, excluding any where less than 40 were exposed to one concentration.

Where it has been necessary to depart from any of the above criteria (see, for example, the results on A. pseudopunctipennis in Peru) this fact is noted under "Remarks". That column is also used to draw attention to proportions of samples which survived exposure to high concentrations, and to record a few results obtained with insecticides other than DDT and dieldrin.

The values in the table are based on figures corrected by Abbott's formula, where the average mortality in the controls lay between 5% and the permitted maximum of 10%.

Records of the "LC_{100}" in Table 2[1]

Some of the tests summarized in this paper were designed primarily to establish the base-line susceptibility of American anophelines in terms of their LC_{50}.

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[1] The importance of finding and re-checking the lowest concentration which consistently gives complete kills has been stressed by the Expert Committee on Insecticides in its description of the WHO test for susceptibility (see Eighth Report, Annex 1, p. 56). But the practice adopted here, of recording such findings under the heading "LC_{100}" awaits official discussion at the forthcoming meetings of the Expert Committee on Insecticides.

Others however were routine checks, run at "the lowest concentration which has consistently given complete kills in the four successive /earlier/ tests" (see Instructions issued with the WHO test kit, para. 1 (c)). The LC_{50} plays no part in these routine checks. On the other hand, if the chosen concentration now fails to kill all the specimens, the investigator is directed to test at a higher one (or failing that, for a double exposure-period). Thus his single aim in the checks is to obtain a consistent 100% kill.

Since that aim is proper also to the tests for base-line susceptibility (see para. 1 (b) of the Instructions) it has been deemed essential in this summary to record wherever possible the concentration that gave complete kill (or else the failure to obtain complete kill) alongside the LC_{50} values obtained. This has been done under the convenient heading "LC_{100}", although of course no amount of testing can prove that a concentration would kill every specimen of the sampled population.

An additional reason for recording the "LC_{100}" next to the LC_{50} is that the relationship between the two values has a bearing on the question whether a factor for resistance is present. In homogeneous susceptible populations the "LC_{100}" appears always to be not more than 10 times greater than the LC_{50}: frequently the factor is five or under. Therefore a population which at the first series of tests shows any survivors to a concentration ten or more times the LC_{50} falls at once under suspicion of containing resistant individuals.

On the other hand we may wish to judge whether a population having, upon re-test, a somewhat increased LC_{50} is heterogeneous for resistance or homogeneous and vigour-tolerant. If the latter, the relationship between the values of LC_{50} and "LC_{100}" should remain approximately as before. But if the "LC_{100}" is found to have risen much more sharply than the LC_{50} we must conclude that resistant mosquitos are present.

In order to calculate the "LC_{100}" where any mosquito unexpectedly survived exposure to a high concentration such as 1.6% dieldrin, and no complete kill was obtained, the "LC_{100}" is recorded as more than that value. Where complete kill was obtained at one or more concentrations the lowest is designated the "LC_{100}" provided not less than 100 mosquitos were exposed to it. If between 50 and 100 were exposed to it, this concentration is recorded as the "indicated LC_{100}" by the placing of the abbreviation "ind" before the "basis" number of observations.

TABLE 1. SUMMARY OF CONFIRMED FINDINGS OF INSECTICIDE RESISTANCE IN ANOPHELINES IN THE FIELD (up to 1 April 1959)

Region and species	Country	Locality or area	Resistant to	Susceptible to	Investigator	Date proved	Retested	Remarks
AMERICAS								
albimanus	El Salvador	Tecomatal	DDT and dieldrin	-	Duret	July 1958		
		Sirama	DDT and dieldrin	(malathion)	Duret	July 1958	Jan. 1959	Malathion test by Parada, Jan. 1959
		Olomega	DDT and dieldrin	(malathion)	Duret	July 1958	Jan. 1959	Malathion test by Parada, Jan. 1959
		La Libertad	dieldrin	DDT	Duret	July 1958	March 1959	Retest indicated DDT resistance
		Acajutla	dieldrin	DDT	Duret	July 1958		
		Metalio	dieldrin	DDT	Duret	July 1958		
		San Rafael	DDT and dieldrin	malathion	Parada	Feb. 1959		
		San Domingo	DDT and dieldrin	malathion	Parada	Feb. 1959		
		Melara	DDT and dieldrin	malathion	Parada	Feb. 1959		
	Guatemala	Finca Varsovia	dieldrin	DDT	Dary	Sept. 1958		
		Puerto San José	dieldrin	DDT (?)	Dary	Sept. 1958		
		Nueva Concepcion	dieldrin	DDT	Dary	Aug. 1958	Oct. 1958	
		Zacapa	dieldrin	DDT	Dary	Sept. 1958		
	Nicaragua	Chinandega	dieldrin	DDT	Heredia	Oct. 1958		
		Managua	DDT and dieldrin	-	Heredia	Oct. 1958	Dec. 1958	
	Honduras	Comayagua	DDT and dieldrin	-	Austin	Nov. 1958		
		Namasique	dieldrin	DDT	Austin	Nov. 1958		
		La Isla	dieldrin	DDT	Austin	Feb. 1959		
	Br. Honduras	Belize	dieldrin	DDT	Heredia	Feb. 1959		

TABLE 1. (continued) SUMMARY OF CONFIRMED FINDINGS OF INSECTICIDE RESISTANCE IN ANOPHELINES IN THE FIELD (up to 1 April 1959)

Region and species	Country	Locality or area	Resistant to	Susceptible to	Investigator	Date proved	Retested	Remarks
AMERICAS (cont.)								
aquasalis	Trinidad	Barataria	dieldrin	DDT	Omardeen	Sept.1958		
		Moruga	dieldrin	-	van Seventer	March 1959		
pseudo-punctipennis	Mexico	Morelos	dieldrin	DDT	Martinez Palacios	Sept.1958		
quadrimaculatus	USA	Tennessee Valley	DDT	-	Krusé et al.	1951		Larval tests. Confirmed by Gartnell & Ludvik
		Bolivar, Miss.	dieldrin	DDT	Mathis et al.	1955		
		Mississippi Hills	dieldrin	DDT	Quarterman	Sept.1957		
AFRICA								
gambiae	Nigeria	W. Sokoto	dieldrin	DDT	Elliott & Ramakrishna	Nov. 1955	1956-58	Confirmed by Armstrong et al.
		Kano	dieldrin	DDT	Elliott & Armstrong	1956		30% of adults resistant (BHC pressure)
	Haute Volta	Pala (Bobo-Dionlasso)	dieldrin	DDT	Hamon et al.	July 1957	1958	
	Côte d'Ivoire	Abidjan	dieldrin		Adam et al.	Feb. 1958		Larval tests
	Liberia	Kpain	dieldrin	DDT	Ramsdale	Oct. 1957	April-July 1958	Confirmed by Guttuso
		Graie	dieldrin	DDT	Schoof	Oct. 1957		
		Gbedi	dieldrin	DDT	Schoof	Oct. 1957		
		Bahn	dieldrin	DDT	Schoof	Oct. 1957		

TABLE 1. (continued) SUMMARY OF CONFIRMED FINDINGS OF INSECTICIDE RESISTANCE IN ANOPHELINES IN THE FIELD (up to 1 April 1959)

Region and species	Country	Locality or area	Resistant to	Susceptible to	Investigator	Date proved	Retested	Remarks
EUROPE AND EAST MEDITERRANEAN								
coustani	Saudi Arabia	Dhahran	dieldrin	DDT	Peffly	Jan.1958		
fluviatilis	Saudi Arabia	Dhahran	dieldrin	DDT	Peffly	Feb.1959		
pulcherrimus	Saudi Arabia	Dhahran	dieldrin	DDT	Peffly	Feb.1958		
sacharovi	Greece	Pelopponesus	DDT and dieldrin	malathion	Hadjinicolaou and others	1951-54	1957,58	Confirmed in many localities by Belios and de Zulueta
	Turkey	Adana	DDT	dieldrin malathion	de Zulueta Gökberk	June 1958		
sergenti	Jordan	Dead Sea	dieldrin	DDT	Garrett-Jones	Nov.1958	Feb.1959	
stephensi	Saudi Arabia	Dhahran	DDT	dieldrin BHC	Peffly, Davidson	Nov.1955	Oct.1956 May 1958	
	Iraq	Moawiya,etc.	DDT	dieldrin	de Meillon	Nov.1957	March - May 1958	Confirmed by Petridis
	Iran	Khuzistan	DDT	-	Mofidi and others	Oct. - Nov.1957		
		Bandar Abbas	DDT	-	Mofidi and others	Oct. - Nov.1957		

TABLE 1. (continued) SUMMARY OF CONFIRMED FINDINGS OF INSECTICIDE RESISTANCE IN ANOPHELINES IN THE FIELD (up to 1 April 1959)

Region and species	Country	Locality or area	Resistant to	Susceptible to	Investigator	Date proved	Retested	Remarks
SOUTH-EAST ASIA and WEST PACIFIC								
annularis	Indonesia	Central Java	dieldrin	DDT	Chow	May 1958		
barbirostris	Indonesia	Central Java	dieldrin	DDT	Chow	March 1958		
culicifacies	India	Potgaon (Bombay)	dieldrin	DDT	Patel et al.	Oct.1958		
stephensi	India	Madras	DDT	-	Rajagopalan	Nov.1957		Confirmed by Sharma
subpictus malayensis	Indonesia	Central Java	dieldrin	DDT	Chow	May 1958		
subpictus subpictus	Indonesia	Central Java	dieldrin	DDT	Chow Ronnefeldt	Dec.1957		Confirmed by Davidson
	India	Delhi	DDT	dieldrin	Sharma & Krishnamurthi	1957		
	Nepal	Simra	DDT	-	Pant	Sept.1958		
sundaicus	Indonesia	Djakarta	DDT	dieldrin	Crandell	1954 - 56	1958	
		Tzirebon	DDT	dieldrin	Crandell			
		Semarang	DDT	-	Chow & Soeparmo	1955		Confirmed by Davidson
		Surabaya	DDT	dieldrin	Chow & Soevoto	1956		"
	Burma	Akyab	DDT	dieldrin	Delphin	May 1957		
vagus	Indonesia	Central Java	dieldrin	DDT	Chow	March 1958		

TABLE 2

SUSCEPTIBILITY TESTS BY THE WHO METHOD - I:- THE AMERICAN REGION
(Since publication of WHO/Mal/203)

Species	Investigator	Country	Locality (or area)	Spray record	Date	LC_{50} DDT	LC_{100} DDT	LC_{50} dieldrin	LC_{100} dieldrin	Remarks
albimanus	Vargas	Costa Rica	Aranjuez	DDT 14 times	vii.58	<0.5 (60)	<4 (100)	-	-	
"	"	"	"	"	viii-ix.58	<0.25 (180)	-	<0.05 (40)	<0.4 (ind:80)	
"	Duret	El Salvador	Tecomatal	DDT and dieldrin (?)	vii.58	4.2 x 2h	-	>1.6 x 2h	-	
"	"	"	Sirama	"	"	5.5 x 2h	-	>1.6 x 2h	-	
"	"	"	Olomega	"	"	6 - 7 x 2h	-	>1.6 x 2h	-	
"	"	"	La Libertad	"	"	3.4	-	>1.6	-	
"	"	"	Acajutla	dieldrin (?)	"	1.8	-	>1.6	-	
"	"	"	Metalio	"	"	1.1	-	>1.6	-	
"	Parada	"	Sirama	DDT and dieldrin (?)	i.59	>8.0(110)	-	>>1.6 (60)	-	LC_{50} malathion: <0.012%
"	"	"	San Rafael	dieldrin '58	i-ii.59	>8.0 (96)	-	>>1.6 (261)	-	"
"	"	"	Melara	DDT '58	ii.59	>8.0 (115)	-	>1.6 (118)	-	"
"	"	"	Santo Domingo	"	"	>>8.0 (116)	-	>1.6 (119)	-	"
"	"	"	La Libertad	"	iii.59	>>4 (105)	-	>>1.6 (115)	-	4% DDT killed 32% 1.6% dln killed 18%
"	Heredia	Br. Honduras	Belize	DDT 3 x, dln 1 x	ii.59	0.38 (440)	-	1.6± (420)	-	
"	Villavicencio	Ecuador	Guayaquil	"sprayed 2 x"	ii.59	-	-	0.09 (700)	0.4 (239)	
"	Dary	Guatemala	Finca Varsovia	Dieldrin '57,'58;	ix.58	1.3 (296)	>8 (79)	>>1.6 (101)	-	
"	"	"	Barranco Colorodo	Dieldrin '57, '58;	ix.58	-	-	>>1.6 (27)	-	
"	"	"	Aldea el Manglar	Dieldrin '57, '58;	x.58	1.5± (144)	>8 (71)	>>1.6 (71)	-	
"	"	"	Nueva Concepcion	Dieldrin '57, '58;	x.58	<<2 (70)	>8 (50)	>>1.6 (70)	-	
"	"	"	Barranca Seca	Dieldrin '57, '58;	x-xi.58	<<2 (45)	<8 (ind:90)	>>1.6 (45)	-	
"	Austin	Honduras	Namasique	dieldrin	xi.58	-	-	>>1.6 (32)	-	
"	"	"	Las Flores	DDT and dieldrin	xii.58	>8 (245)	-	>>1.6 (157)	-	
"	"	"	La Isla	DDT and dieldrin	ii.59	0.6± (77)	-	>1.6 (28)	-	
"	"	"	Tablón	DDT and dieldrin	i-ii.59	<<2.0 (44)	-	>>1.6 (40)	-	1% DDT killed 21/22
"	Heredia et al.	Nicaragua	Los Tercios	DDT and dieldrin	x.58	3.3 (165)	>8 (80)	>>1.6 (60)	-	
"	Vindell	"	"	"	xii.58-i.59	2.0 x 2h (31)	-	>>1.6 x 2h (43)	-	
"	Heredia	"	Los Martinez	"	x.58	>8 (35)	-	>>1.6 x 2h (23)	-	
"	"	"	Tastasli	"	x.58	<1.0 (55)	<4 (ind:55)	0.3± (161)	>1.6 (54)	
"	"	"	San Ramon	"	x.58	2.5 (132)	-	>>1.6 (65)	-	
"	Vindell	"	"	"	ii.59	>4.0 (37)	-	>>1.6 (38)	-	Resprayed with DDT, December 1958
"	"	"	El Rodeo	no record	ii.59	>>4.0 (40)	-	>>1.6 (40)	-	
"	Martinez	Mexico	Las Canoas, Mich.	DDT '57,dln '58 (vii)	ix.58	<2 (40)	<4 (ind:60)	<0.2 (40)	<1.6 (100)	20 per concentration
"	Palacios	"	Tlacotalpan, Ver.	DDT & dln, '57 (xii)	ix.58	<1 (40)	-	<0.2 (40)	<1.6 (ind:80)	20 per concentration
"	Shields	"	Acapulco	no record	xi.57	-	-	0.06	-	
"	Viramontes et al.	"	El Podrido	unsprayed(dln used 6 miles away)	ii.59	0.8 (241)	4.0 (100)	<0.1 (100)	0.2 (100)	0.1% dln gave 83% mort.
"	Blazquez	Venezuela	Maracay	unsprayed recent yrs.	xi.57	0.004 ppm	-	<0.004 ppm	-	larval tests
"	Brown	Panama	Rio Gatun	no record	vi.58	0.0008 ppm	-	-	-	larval tests
"	"	"	Santa Rosa	"	vi.58	0.0015 ppm	-	-	-	larval tests
"	Conte	"	Hipodromo Ramon	"	vii-viii.58	-	-	<0.1 (64)	0.4 (ind:51)	
"	"	"	Campo Lindbergh	"	viii.58	-	-	<0.1 (83)	0.4 (ind:56)	
"	"	"	La Pita	"	viii.58	-	-	0.038 (266)	0.2 (120)	

TABLE 2 (continued)

SUSCEPTIBILITY TESTS BY THE WHO METHOD - I.- THE AMERICAN REGION

Species	Investigator	Country	Locality (or area)	Spray record	Date	LC_{50} DDT	LC_{100} DDT	LC_{50} dieldrin	LC_{100} dieldrin	Remarks
albimanus	van Seventer	Jamaica	Amity Hall	DDT 7 yrs.; dln '58	xi.58	-	-	0.11 (135)	>1.6 (57)	17.5% survived 1.6%
"	"	"	"	"	xii.58	-	-	0.3± (93)	>4.0 (93)	19% survived 4%
"	"	"	"	"	xii.58	-	-	-	>4.0 x 8h (85)	14% survived 4% x 8 hours
"	"	"	Big Bridge	DDT/BHC ante;dln '58	xi.58	-	-	<0.1 (37)	0.4 (108)	
"	"	"	"	"	i.59	-	-	<0.1 (ind:30)	1.6 (97)	
"	"	"	Dover	DDT 10 yrs.; dln '58	i.59	0.36	-	<0.05	>1.6 (45)	
"	"	"	Frome	dln '58	xii.58	-	-	<0.1 (ind:20)	>4.0 (76)	1/25 survived 4%; all (51) killed at 0.4, 0.8 & 1.6%
"	"	"	Salt River	DDT 10 yrs.; dln '58	xi.58	-	-	<0.4 (ind:28)	>1.6 (74)	
"	"	"	"	"	xi.58	-	-	-	>1.6 x 2h (93)	13% survived 1.6% x 2hrs
"	"	"	"	"	i.59	<0.25 (41)	2 (ind:55)	-	>4.0 (49)	1/49 survived 4%
"	"	"	Pedro Bay	DDT, only	xi.58	-	-	<0.4 (43)	<1.6 (ind:85)	
"	Rice	"	St Andrew	"endrin on sugar"	xi.58	-	-	0.2± (115)	>1.6 (29)	(also 1/49 survived 1.6% x 2 hours)
albitarsis	Ferrer	Colombia	Pompeya	DDT	vii.58	0.75 (559)	<8 (ind:92)	0.08 (395)	<1.6 (ind:90)	
"	Pereira	Paraguay	Minas-cué	no record	xi.58	-	-	0.1± (123)		
"	"	"	Cerro Lorito	"1958"	xii.58	-	-	0.035 (302)	0.4 (99)	
"	"	"	Puerto Pinasco	"	xii.58	-	-	0.03 (302)	0.4 (101)	
aquasalis	Omardeen	Trinidad	Barataria	DDT, 1946-57, dln viii.58	viii.58	-	-	0.8-1.6 (300)		mortalities erratic
"	"	"	"	"	viii.58	-	-	0.2± x 8h (360)	>1.6 x 8h (59)	
"	"	"	"	"	ix.58	1.1 (435)	4.0 (130)	>>1.6 (256)	-	
"	"	"	"	"	x.58			1.6 x 8h (400)	-	4-hour exposures to 1.6% gave similar kill; also 1-hour exposures to 4% (596 mosquitos)
"	van Seventer	"	Moruga	DDT, 57; dln, 58	iii.59			>>1.6 (119)	-	
neomaculipalpis	Conte	Panama	Tocumen	no record	xii.58	-	-	<0.1 (34)	<0.4 (ind:57)	
pseudopunctipennis	Pletsch	Mexico	Acatlipa	DDT	xi.58	<0.1 ppm	-	1.2 ppm (ind:50)	-	larval tests
	Martinez Palacios	"	Temixco, Mor.	DDT 2 x,57; dln 58	vii.58	1.1 (300)	4.0 (100)	>>1.6 (20)	-	F_2 tested (reared Mex.City)
"	"	"	"	"	viii-ix.58	0.97 (100)	-	>>1.6 (40)	>1.6 x 16h (20)	Tested on spot. 1.6% x 4, 8 and 16 hours killed 55-75%
"	"	"	Acatlipa, Mor.	"	ix.58	-	-	-	>1.6 x 16h (20)	Mort. 80% /20 per exposure/
"	"	"	Santa Ines, Mor.	DDT only, 56-58	ix.58	<1.0 (40)	-	<<0.4 (40)	<0.8 (ind:60)	0.1% dln killed 10/10
"	"	"	Izucar, Pue	"	ix.58	1.1 (120)	-	0.12 (120)	<1.6 (ind:60)	
"	"	"	Casa Blanca, Pue	dln, xi.57	ix.58	0.6± (180)	4.0 (ind:60)	0.10± (120)	<0.8 (120)	from sprayed houses
"	"	"	C.d.l. Coyote, Mor.	unsprayed	ix.58	<2 (40)	-	<0.4 (40)	>1.6 (20)	
"	"	"	Uspero, Mich.	DDT '56; dln '57	ix.58	0.5-2.0 (60)	-	0.1-1.6 (100)	>1.6 x 16h (20)	morts. from 1 hour dln were 35-65% (20 per concentration)
"	"	"	La Tuna, Mich.	"	ix.58	-	-	>0.4 (40)	>1.6 x 4h (20)	
"	"	"	San Antonio, Mich.	DDT; dln 57 & vii.58	ix.58	<2 (40)	-	<0.2 (40)	>1.6 x 16h (100)	1/100 survived exps. to 1.6% for 16 hours (or less)

TABLE 2 (continued)

SUSCEPTIBILITY TESTS BY THE WHO METHOD - I:- THE AMERICAN REGION

Species	Investigator	Country	Locality (or area)	Spray record	Date	LC_{50} DDT	LC_{100} DDT	LC_{50} dieldrin	LC_{100} dieldrin	Remarks
pseudopuncti-	Acosta	Peru	Corral de Hoyos	DDT '55-56	i.58	0.4 (298)	-	-	-	About 50 specimens per tube
pennis	"	"	Vitarte (Lima)	DDT 48-55	iv.58	0.6 (231)	-	0.17 (210)	-	27-38 specimens per tube
"	"	"	San Jose (ICA)	DDT, BHC, dln 52-53	v.58	-	-	0.18 (914)	-	20-34 specimens per tube
"	"	"	Hacienda Huamani	"	v.58	-	-	0.26 (384)	-	20-32 specimens per tube
"	"	"	Fundo Pacaynio	DDT-BHC, 53-55	v.58	-	-	0.23 (174)	-	26-32 specimens per tube
"	"	"	El Puente (Arequipa)	DDT 47-50;BHC-dln '53	iv.58	0.45 (273)	-	0.15 (407)	-	24-32 specimens per tube
"	"	"	Characta (Arequipa)	"	vi.58	0.86 (470)	-	0.10 (268)	-	DDT 20-34 per tube; other tests with 38-50 per tube gave average mortality 28% only, on 1% DDT
"	"	"	Pampa del Carmen	unsprayed	vii.58	-	-	0.51 (168)	-	26-30 specimens per tube
"	"	"	Juan Jui	"	viii.58	1.1 (152)	-	-	-	36-40 specimens per tube
"	"	"	Hacienda Ninabamba	"	xi.58	-	-	0.28 (413)		20-34 specimens per tube (NB: Highest concs. not included in this series)
punctimacula	Conte	Panama	La Pita	no record	viii.58			<0.05		
"	"	"	Salud	"	xi.58	0.3		<0.05		
"	Vargas	Costa Rica	Matapalo	DDT 17 x	ii.59	0.27 (240)	-	-	-	
quadrimacu- latus	Ford	USA	Orlando, Fa	no record	xii.58	<0.004 ppm		0.12 ppm		Larval tests. LC_{50} BHC : 0.15 ppm