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DDT RESISTANCE IN SIMULIUM DAMNOSUM s.l. (DIPTERA, SIMULIIDAE) IN WEST AFRICA[1]

by

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In West Africa Simulium damnosum s.l. may locally develop a high level of resistance to DDT. A probable relationship between such resistance and the sometimes intensive agricultural use of DDT has been established. Although these resistance phenomena are very localized, they may have some repercussions on the extensive Onchocerciasis Control Programme being carried out by the World Health Organization in West Africa.

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DDT has been widely used in West Africa for the control of blackfly larvae of the S. damnosum s.l. complex.

Between 1960 and 1971, in control campaigns in the Volta basin area, high concentrations of DDT (0.1 ppm/30 min) were applied weekly to rivers (Le Berre et al., 1964; Philippon & Le Berre, 1974). From 1970 onward the treatment supervisors noted a quite marked decrease in the efficacy of DDT on certain stretches of water (the Comoé at Folonzo, the lower Bandama).

At Kainji in Nigeria the effective concentrations of DDT doubled between 1961 and 1968, a sign of a decrease in the susceptibility of the larvae of S. damnosum s.l. (Walsh, 1970).

In Ghana, on the lower reaches of the Volta, Kuzoe & Noamesi (in: Brown & Pal, 1973) also noted a decrease in the efficacy of DDT and a decrease in the LC_{50} values (obtained by the method of Muirhead-Thomson, 1957).

In Upper Volta, Quélennec & Vervent (1970) showed that in areas of onchocerciasis vector control, S. hargreavesi could rapidly develop resistance to DDT.

Outside Africa, resistance of Simuliidae larvae to DDT has been reported in Japan with S. aokii (Suzuki et al., 1963) and with S. ornatum (Asahina et al., 1966); in the United States and Canada with S. venustum and S. fuscum (West, 1967; Jamnback & West, 1970).

MATERIALS AND METHODS

The methodology for testing the susceptibility of blackfly larvae to insecticides proposed by Mouchet et al. (1977) was successfully applied.

Field tests were carried out early in the morning and in the evening. For each concentration two batches of 25 larvae of stages 4 and 5 were used, placed in glass bowls containing 250 ml of preoxygenated distilled water. The tests were repeated two to four times, depending on the number of larvae available. The contact time was three hours and mortality was

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assessed by totalling the dead and dying larvae for each concentration (high mortality). The dilutions were obtained from standard ethanol solutions supplied by WHO.

Only the tests in which the temperature remained between 20 and 25°C were taken into account. By analysing the results of 20 tests with temephos on S. damnosum s.s. and S. sirbanum, Grébaut & Guillet (1977) showed that within the 20-25°C range and with a contact time of three hours the temperature has no significant effect on the results of the tests. The temperature cannot therefore explain the wide variations in susceptibility that are encountered. In the case of DDT, however, it should be noted that toxicity generally drops as the temperature increases (Hadaway & Barlow, 1957; Fan Cheng & Richard, in: Brown & Pal, 1973).

In Ivory Coast three susceptible populations of different compositions were tested: S. yahense on the Goué at Wa (south-western Ivory Coast, 7°26'N, 8°10'W), S. sanctipauli on the Bandama at Tiassalé (southern Ivory Coast, 5°56'N, 4°49'W), S. damnosum s.s. and S. sirbanum which predominate on the Boa at Tjokoronidougou in the dry season (north-western Ivory Coast, 8°41'N, 7°22'W).

Within the boundaries of phase III of the Onchocerciasis Programme in the Volta Basin Area, four populations of S. damnosum s.s. and S. sirbanum with low susceptibility or resistance to DDT were tested: in Mali on the Banifing II (11°45'N, 7°10'W) and on the Baoulé (12°30'N, 6°50'W), in Benin on the Kiatiko (10°18'N, 1°22'E), and in Togo on the Sossoa (9°42'N, 1°15'E).

A resistant population consisting mainly of S. soubrense was tested at Bouaflé on the Marahoué (central Ivory Coast, 7°N, 5°45'W).

RESULTS

Table 1 gives the results obtained with the three susceptible populations tested in Ivory Coast. The corresponding concentration-mortality regression lines are presented in Figs 1 and 2.

In order to compare these results with those obtained with resistant populations, the arithmethic means of the LC_{50} and LC_{95} values were calculated (0.045 and 0.12 ppm respectively). The substantial variations found in the LC_{100} values will be noted. The populations tested on the Bandama and Boa (March 1977) do not display similar susceptibility to those on the Goué and Boa (March 1976). Nevertheless, they are regarded as susceptible in view of the concentration-mortality ratio and the LC_{95}/LC_{50} ratios (3.3 and 3.4).

Table 2 gives the results obtained from populations with low susceptibility or resistance to DDT. The coefficient of resistance is the ratio between the LC_{95} observed and the mean LC_{95} in susceptible populations. The corresponding regression lines (Figs 1 and 2) have the characteristic appearance of DDT resistance: normal mortality at low concentrations and a very marked plateau at high concentrations.

Two levels of resistance were found:

- a high level (coefficient of resistance above 21) for the populations of the Banifing II (Mali) and the Marahoué (Ivory Coast);
- a moderate level (coefficient of resistance 10.4) for the populations of the Kiatiko (Benin) and the Sossoa (Togo).

DISCUSSION

Up to now DDT resistance in S. damnosum s.l. has never been categorically proved.

The levels of resistance mentioned here for West Africa are higher than those reported by Suzuki et al. (op. cit.) (coefficient of resistance = 12.8) and by West and Jamnback & West (op. cit.) (coefficient of resistance = 5-7) in palaearctic and nearctic blackflies.

It is also pointed out that on the Boa the LC_{95} increased by a factor of 2.7 in one year, indicating a possible regression of DDT susceptibility.

This resistance is occurring in the blackfly populations of three temporary rivers with a low discharge and one permanent river, the Marahoué. None of these rivers had at the time ever been subjected to a blackfly control campaign. They flow through areas where cotton is intensively cultivated, and each rainy season the cotton crop is treated with 8-10 kg of DDT per hectare. Some of this DDT is carried away by the rivers on the account of the very substantial run-off. The exposure of S. damnosum s.l. larvae to low concentrations of DDT for several months may be sufficient to account for the level of resistance mentioned. This phenomenon is commonly observed among the Culicidae.

The agricultural use of DDT is still very widespread in West Africa. Consequently, few data have been collected on the basic susceptibility to DDT of S. damnosum s.l.

On a more general level, and within the current context of the extensive Onchocerciasis Control Programme in West Africa, the mechanisms of the development of insecticide resistance in S. damnosum s.l. are certainly a very complex matter. Two groups of opposing factors must be particularly involved.

Factors favourable to the developement of resistance: the very strong selective pressure exerted by the insecticides because of the constantly increasing area of the treated zones (at present one area alone is 700 000 km^2) and the frequency of larvicide treatment (once a week) on the one hand and the short duration of the development cycle (8-15 days) on the other hand.

Factors unfavourable to the development of resistance: the phenomena of dispersion and migration, very marked in S. damnosum s.l. females, causing the massive introduction into treated areas of fertilized females from untreated areas. This leads to dilution of any resistance genes present in the treated population and keeps the frequency of such genes below a critical threshold. This phenomenon was recently studied from the theoretical viewpoint by Comins (1977).

CONCLUSION

The level of susceptibility of S. damnosum s.l. larvae to DDT is on the whole rather varied and some cases of high resistance have been reported. Although sporadic and localized, these cases are very important because they definitely prove that S. damnosum s.l. has the capability to develop a certain level of DDT resistance fairly rapidly.

It is likely that the use of DDT in the Regional Onchocerciasis Control Programme would have led to the appearance of widespread resistance to this insecticide. This casts great doubt on the advisability of using DDT analogues in the control of S. damnosum s.l., as cross-resistance phenomena are common in this group of insecticides particularly in the biodegradable analogues. For example, a very high level of cross-resistance is observed between OMS-1476 and DDT in the Culicidae (Quiroga et al., 1976).

At present the only group of insecticides really suitable for use in onchocerciasis control in West Africa remains the organophosphorus compounds; Guillet & Grébaut (unpublished document) have not so far recorded any reduction in susceptibility to temephos in populations treated regularly for more than five years.

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TABLE 1. CHARACTERISTIC VALUES OF POPULATIONS SUSCEPTIBLE TO DDT

Locality, river, country	Species	Date	LC_{50} ppm	LC_{95} ppm	Range of LC_{100}	Ratio $\frac{LC_{95}}{LC_{50}}$
Wa, Goué, Ivory Coast	S. yahense	13.05.77	0.037	0.058	0.06-0.12	1.5
Gauthier Falls, Bandama, Ivory Coast	S. sanctipauli	29.03.77	0.053	0.18	0.25-0.50	3.4
Tjokoronidougou, Boa, Ivory Coast	S. damnosum s.s. S. sirbanum S. soubrense S. sanctipauli	9.03.76 15.03.77	0.038 0.052	0.064 0.175	0.02-0.1 0.25-0.50	1.6 3.3
Arithmetic mean			0.045	0.12		2.8

TABLE 2. CHARACTERISTIC VALUES OF POPULATIONS RESISTANT TO DDT

Locality, river, country	Species	Date	LC_{50} ppm	LC_{95} ppm	Range of LC_{100}	Ratio $\frac{LC_{95}}{LC_{50}}$	Coefficient of resistance[a]
Sossoa Togo	S. damnosum S. sirbanum	9.11.76	0.029	1.25	>1.25	43	10.4
Banifing II Mali	S. damnosum S. sirbanum	18.02.77	0.098	>2.5	>2.5	>25.5	>21
Bouaflé Marahoué Ivory Coast	S. soubrense dominant	18.02.76	0.44	>2.5	>2.5	>5.7	>21
Kiatiko Benin	S. damnosum S. sirbanum	3.11.76	0.038	1.25	>1.25	32.8	10.4
Taouba Baoulé Mali	S. damnosum S. sirbanum	14.02.77	0.092	0.62	1.25-2.50	6.7	5.2

[a] Ratio of LC_{95} of resistant population to LC_{95} of susceptible population.

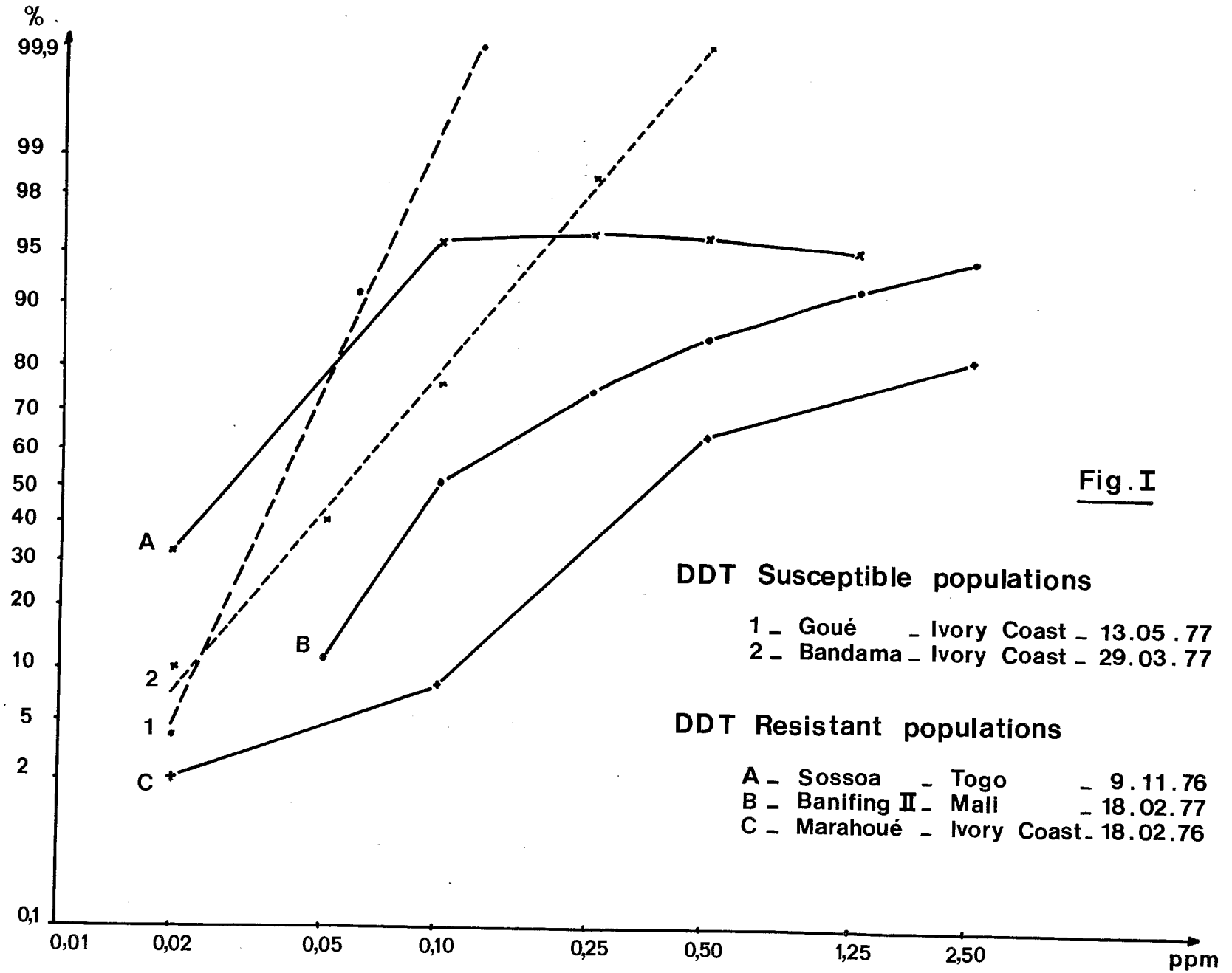

FIG. 1. CONCENTRATION - MORTALITY REGRESSION LINES FOR DDT SUSCEPTIBLE AND RESISTANT POPULATIONS

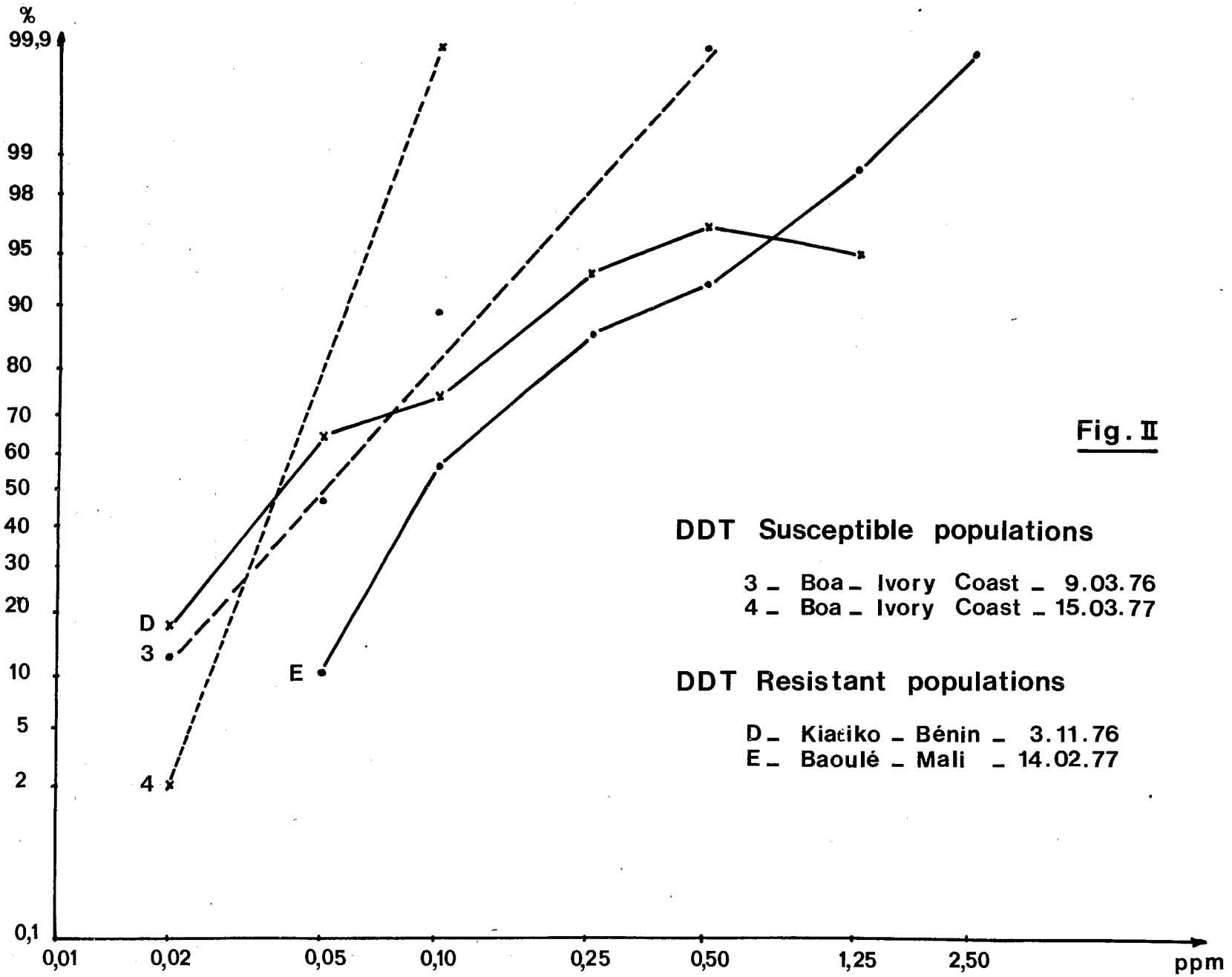

FIG. 2. CONCENTRATION - MORTALITY REGRESSION LINES FOR DDT SUSCEPTIBLE AND RESISTANT POPULATIONS