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INSECTICIDE RESISTANCE IN BLACKFLY OF THE SIMULIUM DAMNOSUM COMPLEX IN WEST AFRICA

by

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1. INTRODUCTION

The Onchocerciasis Control Programme is currently based on control of blackfly larvae, for which temephos is practically the only insecticide available. Continuing determination of the susceptibility of Simulium damnosum s.l. to this compound is therefore vital for control operations. In the case of local failure of insecticide application there needs to be some way to determine whether this was due to application errors, a bad insecticide formulation or to genuine temephos (Abate^{R}) resistance. Further, new products should be selected only from compounds to which blackfly have not yet developed resistance, as a result, for example, of the agricultural use of such compounds.

It would also be useful from the standpoint of possible adult blackfly control to gather background information on the susceptibility of S. damnosum s.l. adults to the compounds contemplated for the purpose.

In order to carry out such studies in the programme zone, a reliable and reproducible test method had first to be developed. Once this problem was solved, it was possible to collect background data on S. damnosum s.l. susceptibility and to contemplate a system for providing surveillance of resistance.

2. TEST TECHNIQUES

(a) Testing larvae

Mouchet et al. (1977) reviewed the different methods proposed for evaluating the susceptibility of blackfly larvae, but none of them was found to be applicable under field conditions in the Programme zone.

The following method was then proposed by these authors. S. damnosum larvae taken from larval sites were tested on the spot or nearby. Fourth and fifth stage specimens were divided into batches of 25 and placed in bowls containing the appropriate dilution of insecticide. The bowls were placed in the shade, where possible in wet sand. After three hours contact the number of dead larvae were counted. Larvae were considered to be dead when they were no longer able to curl up when touched. A subjective element clearly enters

into the assessment of mortality, but this drawback is obviated if the tests are made by the same person each time or by properly trained staff. After being tested, the specimens are examined once more to make sure they are in fact stage 4 and 5 S. damnosum larvae, because the susceptibility of stage 6 and 7 larvae is lower, and fluctuates.

Tests carried out in 1976 in the Ivory Coast and Mali, and later throughout the Programme zone, by staff from the Institut de Recherches sur l'Onchocercose (IRO), Bouaké, Côte d'Ivoire showed that the above method gave regression lines that were perfectly valid from the statistical point of view. Mouchet et al. (1977) also proposed a simple method based on the use of a single diagnostic dose in cases where very few larvae were available. The temephos dose was fixed at 0.25 ppm for three hours. The same method was found to be feasible for testing susceptibility to DDT and chlorphoxim.

The method was also found applicable to other rheophile larvae of insects such as the Trichoptera and might usefully be employed to compare the susceptibilities of blackfly and members of the nontarget insect fauna.

(b) Testing adults

The WHO method proposed for testing the susceptibility of adult mosquitos, consisting of exposure to impregnated papers, was tried out on S. damnosum in the Ivory Coast, where it gave good, reproducible results with malathion. The method, however, was found to be unsuitable for pyrethroids because their very fine crystals migrate into the body of paper, which thereby loses some of its toxicity.

Depositing insecticides on glass slides instead of impregnated paper is now being studied at the IRO. It is hoped to develop a technique for comparing the toxicities of different adulticides and perhaps also their residual effects.

3. SUSCEPTIBILITY OF S. DAMNOSUM IN THE PROGRAMME ZONE

3.1 Temephos

The susceptibility of S. damnosum to temephos was tested in a number of untreated localities: 4 in Niger, 4 in Benin, 2 in Togo and 10 in the Ivory Coast. The results showed that the basic susceptibilities of the different species groups of the complex varied, but that the LC_{50} and LC_{95} were homogenous within each group (Table 1). The LC_{95}/LC_{50} ratios varied from 2.3 to 4. From this data it was concluded that there was no resistance to temephos in the West African regions investigated.

In addition, a test carried out at the Léraba river during an experimental break in insecticide application gave normal results, proving that more than five years of continuous application had had no adverse effect on susceptibility. The LC_{50} was 0.05 ppm, and the LC_{95} 0.17, for the group S. damnosum-S. sirbanum.

3.2 DDT

When studies first began in 1976, it became evident that a number of strains of S. soubrense at Danangoro, Ivory Coast, were resistant to DDT. This resistance is in fact much more widespread and includes the S. damnosum-S. sirbanum group (Guillet et al., 1977). The resistance coefficient for S. soubrense on the Marahoné at Bouaflé and for S. damnosum and S. sirbanum on the Banifing II in Mali can be over 20. A mean resistance coefficient of 10 has been observed among S. damnosum-S. sirbanum on the Kiatito in Benin and on the Sossoa in Togo (Tables 2 and 3).

These rivers have never been treated with DDT for the control of blackfly larvae. However, the insecticide is widely used in all the districts concerned to control cotton pests. The agricultural use of insecticides unquestionably seems to be implicated in the development of resistance to DDT, as has been confirmed by the work of Quélennec et al. (1977), which showed that large amounts of DDT and its metabolite DDE were to be found in the mud of the Bandama and in its fish population.

3.3 Chlorphoxim

Tests were made in one locality in Mali and four localities in the Ivory Coast. The LC_{50} of the S. damnosum-S. sirbanum group on the Baoulé in Mali varied from 0.0017 to 0.019 or by a factor of nearly 10 but the LC_{95} varied only between 0.025 and 0.1. It should be noted that some tests gave a LC_{95}/LC_{50} ratio of as much as 25, which raises doubts about the susceptibility of the strain. As the strains in this locality also show moderate resistance to DDT, studies need to be undertaken to make sure that this rise in the LC_{95} does not indicate that cross resistance between the two insecticides is beginning to develop (Table 4).

In the Ivory Coast at Wa and Madinani the susceptibility of the two species, S. yahense and S. squamosum, is characterized by LC_{50} values of 0.0045 and 0.008 ppm and by LC_{95} values of 0.24 ppm. The LC_{95}/LC_{50} ratio given by these two tests were 5.3 and 3 respectively.

Again in the Ivory Coast, at Gauthier on the Bandama, the LC_{50} for S. sanctipauli was 0.0015 and the LC_{95} 0.0047. The LC_{95}/LC_{50} ratio was 3.1. It should be noted that in this area S. sanctipauli is susceptible to DDT.

4. OUTLOOK FOR THE DEVELOPMENT OF RESISTANCE

Is it possible to predict now whether blackfly of the S. damnosum complex will develop resistance to temephos and if so when? Our opinion is that no answer can be given to this question as long as there are no laboratory techniques for subjecting these insects to selection pressure. What is more, nothing is known of the mechanisms of any resistance blackfly may develop to organophosphorus compounds as such resistance has never been observed. There is agreement that two factors contribute to the development of resistance, one is very high insecticide pressure and the other the speed of the insect's development cycle and its prolificacy.

The Programme zone is subjected to very heavy insecticide pressure since all larval sites in a continuous area of 700 000 km^2 are treated once a week. However, it should be noted that S. damnosum s.l. has completely disappeared in some places and can therefore no longer develop resistance there. In addition, reinvasion, far from posing a threat, tends on the contrary to "dilute" the genes of resistance whenever these appear in border zones, since the invading flies come from non-treated areas.

However, S. damnosum s.l. has a very fast reproduction cycle (35 generations a year) and lays a very large number of eggs (100 to 400 eggs per laying), which would definitely help to contribute to the development of resistance. Furthermore, selection pressure is known in many cases to be triggered by the use of insecticides in agriculture. Blackfly are not exempt from this, as is shown by their resistance to DDT in West Africa. Up to now organophosphorus compounds have been little employed in agriculture in the Programme zone but their use appears to be expanding with the increase in high yield crops (sugar cane, cotton, etc.). Unfortunately, this is a trend we can see coming but nothing can be done to mitigate its effects.

Nevertheless, there are no grounds for concluding that resistance to temephos will appear in the next 15 years. Mosquito populations are known that have been treated with organophosphorus compounds for over 10 years and have never shown any resistance to these products.

5. CONCLUSION

Studies of blackfly susceptibility to insecticides in the Programme zone have up to now been carried out by the IRO at Bouaké. In view of their usefulness for the Programme it would seem an essential step to set up a surveillance system within the zone as part of entomological evaluation.

The methods for determining susceptibility are reliable but the tests need to be carried out by properly trained staff with experience in handling blackflies in the field. This is a necessary condition for results that are comparable and capable of showing up any decline in the susceptibility of blackfly populations treated regularly with temephos.

The risk of temephos resistance needs to be taken very seriously and the Programme authorities need to encourage the search for alternative compounds belonging to other groups of chemical compounds.

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TABLE 1. MEAN SUSCEPTIBILITY TO TEMEPHOS OF DIFFERENT SPECIES GROUPS OF THE *SIMULIUM DAMNOSUM* COMPLEX IN THE ONCHOCERCIASIS CONTROL PROGRAMME

	LC_{50} ppm			LC_{95} ppm			Ratio $\frac{LC_{95}}{LC_{50}}$			No. of tests made
	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	
S. damnosum *S. sirbanum*	0.064	0.041	0.027	0.16	0.11	0.09	4	3	2.3	19
S. soubrense *S. sanctipauli*	0.028	0.02	0.019	0.09	0.06	0.05	3.3	2.8	2.6	9
S. yahense *S. squamosum*		0.045			0.11			2.4		3

TABLE 2. CHARACTERISTIC LETHAL CONCENTRATIONS FOR BLACKFLY POPULATIONS OF THE SIMULIUM DAMNOSUM COMPLEX 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 May 1977	0.037	0.058	0.06-0.12	1.5
Gauthier Falls Bandama Ivory Coast	S. sanctipauli	29 March 1977	0.053	0.18	0.25-0.50	3.4
Tjokoronidougou Boa Ivory Coast	S. damnosum S. sirbanum	09 March 1976	0.038	0.064	0.01-0.1	1.6
	S. soubrense S. sanctipauli	15 March 1977	0.052	0.175	0.25-0.50	3.3

TABLE 3. CHARACTERISTIC LETHAL CONCENTRATIONS FOR BLACKFLY POPULATIONS OF THE SIMULIUM DAMNOSUM COMPLEX 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]
Sossa Togo	S. damnosum S. sirbanum	09 November 1976	0.029	1.25	> 1.25	43	10.4
Banifing II Mali	S. damnosum S. sirbanum	18 February 1977	0.098	> 2.5	> 2.5	> 25.5	> 21
Bouaflé Marahoué Ivory Coast	S. soubrense dominant	18 February 1976	0.44	> 2.5	> 2.5	> 5.7	> 21
Kiatiko Benin	S. damnosum S. sirbanum	03 November 1976	0.038	1.25	> 1.25	32.8	10.4
Taouba Baoulé Mali	S. damnosum S. sirbanum	14 February 1977	0.092	0.62	1.25-2.50	6.7	5.2

[a] The coefficient of resistance is the ratio of the LC_{95} of the DDT resistant population to the LC_{95} of susceptible populations.

TABLE 4. SUSCEPTIBILITY TO CHLORPHOXIM OF FOUR BLACKFLY POPULATIONS OF THE SIMULIUM DAMNOSUM COMPLEX IN MALI AND THE IVORY COAST

Country	River and locality	Species	LC_{50} ppm	LC_{95} ppm	Range of LC_{100}	Ratio $\frac{LC_{95}}{LC_{50}}$
Mali DDTR x 5,2	Baoulé at Taouba	S. damnosum S. sirbanum	0.0035	0.068	0.1-0.25	19.4
DDT S Ivory Coast	Bagoé at Madinani	S. yahense S. squamosum	0.008	0.024	0.025-0.05	3
	Bandama at Gauthier	S. sanctipauli	0.0015	0.0047	0.005-0.0125	3.1
	Goué at Wa	S. yahense	0.0045	0.024	0.05-0.1	5.3