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EVALUATION OF NEW BLACKFLY LARVICIDES FOR USE IN ONCHOCERCIASIS CONTROL IN WEST AFRICA[1]

by

C. Dejoux[2] and P. Guillet[3]

For the last four years the chemical control of Simulium damnosum s.l. in West Africa has been successfully carried out using temephos (Abate^R - 200 CE Procida), an organophosphorus insecticide used as an emulsion concentrate. Continuous research is, however, in hand with the object of selecting an alternative insecticide to temephos, which should, if possible, be of a different nature. While being as effective as temephos against S. damnosum s.l. larvae, this new product should preferably be no more toxic to the non-target fauna than temephos, so as to protect the freshwater environment against any pollution harmful to established biological balances.

The object of the present trials was, therefore, to study the effectiveness of three new formulations against S. damnosum s.l. larvae and to determine in situ their effect on the non-target fauna.

1. APPLICATION POINTS: LOCATION AND DESCRIPTION

That part of the study carried out in Mali took place in the period 23-28 October 1978 in the Toukoto region, west of Bamako (Fig. 1). The rivers treated were the Bakoye, the Baoulé, the Badinn-ko and the Darouma. All these rivers are tributaries of the Sénégal and are hydrologically of the Sahel type, with a low-water period between February and June and flooding between August and November. The experiments were carried out at the end of October, as water level fell progressively. The conditions were favourable for the evaluation of the larvicides: water discharges were adequate, the breeding sites were numerous and accessible, and there were abundant populations of larvae, mainly Simulium sirbanum and, to a lesser extent, S. damnosum s. In general, water transparency was low (15-30 cm measured by Secchi disk) and the suspended particule load relatively high.

2. THE PRODUCTS TESTED - DESCRIPTION

2.1 Reldan^R

Chlorpyrifos-methyl (OMS-1155) produced by Dow Chemical Co. was a suspension of digestible microcapsules containing 100 g of active ingredient/litre.

Two batches were tested: batches C and D, consisting of capsules of roughly the same diameter (respectively 10.4 and 10.8 µm on average), and of the same thickness.

Only batch C was tested for its toxicity against non-target fauna, at a dosage rate of 0.05 ppm/10 min.

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[2] ORSTOM Hydrobiologist, B.P. 1434, Bouaké, Ivory Coast.

[3] ORSTOM Medical Entomologist, OCCGE, B.P. 1500, Bouaké, Ivory Coast.

It is difficult to make use of the results obtained, owing to the deterioration of the two formulations (crystallization of the active ingredient at the bottom of the containers).

2.2 Actellic[R] M 20

Pirimiphos-methyl (OMS-1424) produced by ICI Plant Protection was a suspension of microcapsules containing 200 g of active ingredient/litre. These synthetic polymer microcapsules have an average diameter of 2 µm and a density of 1.05. Although initially intended for use on plants, this formulation roughly meets the standard requirements for blackfly larvicides (Quélennec, 1978).

2.3 K-othrine[R]

Decamethrin (OMS-1998) produced by Roussel-Uclaf was an emulsion concentrate containing 25 g of active ingredient/litre. Two formulations were tested:

A - formulation without a synergist (density at 20°C: 0.92);

B - synergized formulation (density at 20°C: 0.94).

3. METHODOLOGY

3.1 Observations on the target fauna

Treatment was carried out by helicopter.[1] The formulation was released in a single transverse band 100-300 m upstream from the first larval site. A preliminary survey of breeding sites was made the day before treatment and, in some of them, substrates populated by blackfly larvae were marked with strips of coloured cloth.

In so far as possible, a river reach 40-50 km long was examined for each release of the larvicide. Effectiveness was verified 24 and 48 hours after treatment.[2] The estimate of effectiveness is purely qualitative, since only treatments resulting in the detachment of all the larvae are regarded as valid.

3.2 Observations on the non-target fauna

Two techniques were used: first, determination of drift cycles, before and after treatment, in situ and, secondly, quantitative analysis of the rate of drift by the "gutter" method (Dejoux, 1975).

In the first type of study, a natural drift curve is produced by collecting the drifting fauna at specified time intervals. Sampling is always carried out in the same place and the nets employed (two twin nets in most instances) have a mesh size of about 250 µ. Collections are made before, during and after treatment, and the effects of treatment are always reflected in a clear increase in the index of drift (ID).[3] The kinetics of drift and the amplitude of the deviations are directly related to the toxicity of the product tested. In the case of concern to us here, the collection time for each drifting was 30 seconds and current velocity (needed to calculate the volume filtered) was measured by a small current meter at the mouth of the nets.

In the gutter technique, a certain quantity of the aquatic fauna under observation is placed in an adapted system that is partly isolated during the passage of the insecticide. The fauna carried along by the current, after insecticide application, is collected at regular intervals at the end of this system. Subsequent evaluation of the total quantity of fauna tested permits a precise estimate of the quantity affected by the treatment over a given time.

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[1] Identical conditions to those under which operational treatments are carried out.

[2] When all the larvae had become detached from the marked substrates, a more detailed examination of the breeding site was undertaken.

[3] $ID = \frac{N}{V}$ (V = volume filtered during the drift time, N = number of organisms collected in a net during the same period).

The purpose of in situ study of the traumatic drift resulting from the passage of a pesticide is always to evaluate two essential parameters: first, the maximum instantaneous increase, which is the relationship between the maximum value reached by ID after treatment and its normal value estimated immediately before commencement of the reaction of the fauna to the passage of the product.

The second parameter calculated is the weighted increase in the index of drift, which corresponds to the relationship between the mean value of ID calculated over a period of one hour centred on the peak phase of detachment, and the mean value of ID in the hour preceding the start of the effect. This relationship reflects the time distribution of the toxicity of the pesticide, as well as its intensity.

4. RESULTS

4.1 Trials with Reldan[R]

4.1.1 Effects on the target fauna (Table 1)

Batch C at 0.05 ppm/10 min. The partial effect (of the order of 50% detachment) observed over only 2 km may be explained by the presence of microcapsules that were not broken down, or by the presence of numerous crystals of the finely crystallized active ingredient that gradually settled to the bottom. At 0.1 ppm/10 min, this formulation produces detachment of the majority of larvae.

Batch D had no discernible effect at 0.075 ppm/10 min.

It is difficult to interpret these results without knowing the proportion of intact capsules or the behaviour of this deteriorated formulation in the river (the density and dispersion of the broken-down capsules, and the sedimentation of the active ingredient in the free state).

4.1.2 Effects on the non-target fauna

In situ drift cycle

The observations were made on 24 October 1978. Sampling was begun at 6h30 and the larvicide was released at 8h35. Observations were made regularly at two points, one 300 m downstream from the treatment point, the other approximately 10 km downstream.

The larvicide reached the first observation point about 40 minutes after its release. The invertebrate detachment effect was very marked but gradual (Fig. 2). The peak phase was reached about an hour after the commencement of the reaction of the fauna; the maximum value of ID was of the order of 1500.

The resulting maximum instantaneous increase ($\frac{1472.22}{8.33} = 176.7$) and the weighted increase ($\frac{1101.95}{9.45} = 116.57$) are very high and indicate both a strong impact of Reldan C on invertebrates and particularly wide time spread in their detachment.

From 10h00 the fall in the rate of detachment was very steady, apart from a slight peak at 11h00 due to chironomids (Orthocladiinae and Tanytarsini) reaching their maximum rate. However, it remained relatively high until 14h00, making in all five hours with a high rate of detachment.

The taxonomic groups most sensitive to this microencapsulated formulation are Baetidae, chironomids in general, Hydropsychidae and Leptoceridae.

Observations made about 10 km downstream from the distribution point, the object of which was to reveal the effective range against blackflies and also the long-range impact on the non-target fauna, led us to conclude that there was a very slight delayed effect on the latter. The insecticide wave did not reach the observation point until 18h45, or about

10 hours after the release of the capsules. Unfortunately, this timing also corresponds to the start of the normal increase in the index of drift as the invertebrates resume their nocturnal activity. Only comparison of the value obtained for ID at 18h45 on the day of release (48.5) with that obtained at the same hour on the day before (22.3) reveals the slight effect of Reldan C at this distance, mainly on Baetidae. Calculation of the mean values of ID for the period from 18h15 to 21h00 on the day before treatment and on the day of treatment yields respectively 46.52 and 54.82. Although there is a slight increase that can definitely be ascribed to the passage of the pesticide, it is statistically hardly significant.

Lastly, no "trace" of the passage of the product tested could be detected at a third checkpoint about 16 km below the point of release.

Rate of detachment in a gutter

The gutter used, which was positioned on 24 October, immediately below the zone in which the capsules were released, was closed at 6h45 on 25 October, and the first collection of drifting fauna was made at 7h00.

The information on drift in the gutter is summarized in Table 2 and presented graphically in Fig. 2. Only the fauna drifting after the time of passage of the insecticide was considered.

The total detachment (natural drift plus the drift resulting from treatment) was estimated at 63.07% of the fauna tested over a period of 24 hours, which constitutes a very considerable impact, one at a level incompatible with maintenance of the various biological balances of a river. Detachment was particularly catastrophic as regards Baetidae (in the vicinity of 100%!), Trichoptera, Leptoceridae and, in general, all chironomid Diptera.

As an indication, we obtained a detachment of 37.51% of the fauna tested in 24 hours when carrying out a similar treatment with temephos (0.05 ppm/10 min) in an untouched environment, which is an acceptable level for average toxic effect. Under other circumstances, we obtained a maximum instantaneous increase in the ID of 83.33 with temephos 200 CE at a concentration of 0.05 ppm/10 min, as against 176.7 with Reldan C, and a weighted increase in ID of 54.85, as against 116.57 under the same conditions. Consequently, the formulation tested has a higher toxic effect than temephos at the same concentration, and the effect is spread over a far longer period.

4.2 Trials with Actellic^{R} M20

4.2.1 Effects on the target fauna (Table 1)

Actellic M20 had only a very partial effect at 0.075 and 0.1 ppm/10 min. This partial effect was confirmed by detachment of only 17.6% of the blackflies in the gutters set up to study the non-target fauna. Furthermore, the range of the effect was very limited. When the same formulation was tested in floating cages (Guillet & Escaffre, 1979), it produced 97.8 and 100% detachment respectively at 0.25 and 0.50 ppm/10 min. Its spontaneous dispersion is poor and a significant quantity sinks directly to the bottom. It is, moreover, a feature of this formulation that it adheres very strongly to all sorts of substrates. There is the probability that it quite literally lines the bottom and the banks of the river immediately downstream from the treatment point. There is support for this hypothesis in the delayed effect of this formulation, which still produces detachment of the target and non-target fauna 24 hours after treatment 500 m downstream from the treatment point. Despite this delayed effect, many blackfly larvae were found to be alive on inspection after 48 hours.

4.2.2 Effects on the non-target fauna

In situ drift cycle

Treatment was carried out at 9h17 on 26 October 1978.

The first effects became apparent about one hour after the release of the insecticide, the time taken by the product to travel the 300-400 m between the point of impact and the observation post. The detachment of organisms was very gradual and spread out in time; it took two hours for the maximum rate to be reached. Moreover, the index of drift remained very high throughout the rest of the day, and was still 15 times higher on the day after release than it had been the day before, which was an unusual fact and one that had never been observed with the other types of formulations tested previously (Fig. 3).

The maximum instantaneous increase in ID was slightly lower, at 132.44, than the value found for Reldan C, but may be regarded as high, as may the weighted increase (91.31), which is a good reflection of the diffusion in time of the very marked impact of the poison on the invertebrate fauna.

The taxonomic groups that were most sensitive were practically the same as for Reldan (Baetidae and, in general, chironomids); in addition, Tricorythidae were particularly sensitive.

The results obtained at the second checkpoint, set up about 6 km downstream from the point of release, are not such as to justify the conclusion that Actellic in the formulation and concentration tested had a toxic action. It can be estimated that the insecticide reached the checkpoint around six to seven hours after release, i.e. between 15h00 and 16h00. No significant increase in the rate of drift occurred at this time. However, it is possible that a traumatic effect on some organisms superimposed on the natural nocturnal increase in the rate of activity is reflected in the nocturnal drift peak noted at 19h00, but it would be necessary to make a comparison with chronologically corresponding data that it was unfortunately impossible to obtain for material reasons on the day before treatment.

Rate of drift in a gutter

For technical reasons, it was impossible to make observations over a period of 24 hours and the gutter was left in situ for three hours before the passage of the insecticide and for only 12 hours after the commencement of treatment.

The first effects of the passage of the larvicide became apparent about one hour after treatment and were less gradual than in the surrounding natural environment. On the other hand, they were as spread out in time and pointed to continuous toxic action of this formulation over many hours.

The overall drift, summarized in Table 3 and shown graphically in Fig. 3, yields an estimate of 21.3% detachment of the fauna tested over a period of 12 hours. This value may be regarded as high, the more so because the following figures are obtained if we disregard the target group, S. damnosum and other Simuliidae:

Fauna drifting	645
Fauna remaining alive	715
Total fauna tested	1 360
Percentage detachment	47.47%

These results confirm the high toxicity of this Actellic formulation for non-target fauna, and in particular for Baetidae, Tricorythidae, Chironomini and Cheumatopsyche (Trichoptera).

4.3 Trials with K-othrine[R] (Table 1)

4.3.1 Effects on the target fauna

The two formulations, not initially planned to be used in the experiment, were tested only on secondary rivers. Formulation A, tested at 0.02 ppm/10 min, produced total detachment of blackfly larvae and of almost the whole of the entomofauna over the whole length of the river reach (12 km), despite the existence of many slack-water areas. It would therefore seem that this concentration is greatly above the minimum active concentration. At 0.007 ppm/10 min, formulation B was still completely effective over 10 km. At 0.003 ppm/ 10 min, its effect was partial, many older larvae, of instars 6 and 7, surviving the treatment.

4.3.2 Effects on the non-target fauna

In situ drift cycle

A first treatment was carried out at 8h17 on 25 October 1978, at a concentration of 3 ppb/10 min, about 200 m upstream from the observation point where collections of drifting larvae were regularly made. The first effects became apparent at 8h55, i.e. immediately after the insecticide reached the breeding ground. At 9h15, or about 20 minutes after the insecticide reached the checkpoint, the effect was at its maximum. The maximum instantaneous increase was then 87.9, which is relatively high but still an acceptable level.

We then witnessed an extremely rapid decline in ID, which settled back to a practically normal level one hour after maximum impact. The weighted increase of ID is very clear evidence of this brief toxic effect, since it is barely in excess of 21.

As always, Baetidae (Emphemeroptera) were the group most affected, but the fact that it was, overall, very small larvae that drifted shows that the impact of the concentration tested was moderate. Although they were collected in small numbers, it would also appear that Hydracarina are particularly sensitive to decamethrin.

On the Badinn-ko, where treatment was carried out at a concentration of 7 ppb/10 min, we found the effect practically identical to that observed by us on the Baoulé from the kinetic point of view, but extremely violent. Treatment was carried out at 8h25 on 26 October 1978 some 300 m upstream from the checkpoint. The pesticide reached the breeding site that it was intended to treat 30 minutes later and there immediately followed a spectacular detachment of the fauna, which was, moreover, very abundant in that area. The maximum impact was reached after 10 minutes and almost all groups were very appreciably affected, although the Baetidae remained the family that suffered most heavily from the passage of the insecticide. The maximum instantaneous increase, 510.9, was almost six times higher than in the case of treatment at 3 ppb. The weighted increase was also very high (148.5), because of the vast quantity of drifting fauna. However, if we turn to Fig. 4, a perfectly regular and rapid decline in ID values spread out over a period of about one hour is to be seen. No delayed effect was noted for any taxonomic group; the maximum drift always occurred in the first half-hour of the passage of the product (Fig. 4).

Lastly, it should be noted that, in contrast to treatment at 3 ppb, the organisms affected by treatment at 7 ppb were of all instars and that even Oligoneuridae (genus Elassoneuria) and very large Hydropsychidae (genus Amphipsyche) were found in quantity in the drift. Moreover, direct observations made in stagnant zones upstream from the treated breeding site showed that the fauna there had been catastrophically affected and that great numbers of very large insects, such as Gyrinidae (*Orectogyrus* sp.), Dytiscidae (*Cybister* sp.), Hemiptera (primarily Naucoridae and Belostomidae), and also Odonata (*Phyllomacromia* sp., *Pantala* sp., etc.), had perished. On the other hand, no mortality was observed among fish, but the location of the treatment point in a series of rapids at the entrance to a steep-sided canyon made it impossible to trace the effects of treatment downstream.

Rate of drift in a gutter

The first trials carried out in Mali with decamethrin showed firstly that this product, while very effective against *S. damnosum* s.l. at a concentration of 7 ppb/10 min, was also excessively toxic for invertebrates at this concentration. On the other hand, although the toxicity of a concentration of 3 ppb/10 min was acceptable in relation to the non-target fauna, this concentration was unfortunately not completely effective against *S. damnosum* s.l. This led us to test an intermediate concentration of 5 ppb/10 min. For this we employed the usual gutter system, installing it in the Ivory Coast in the river Maraoué, the lower reach of which had not previously been treated with temephos.

In order to quantify more precisely the impact of decamethrin, we carried out a comparative test using, in addition to the gutter into which the decamethrin flowed, another similar one into which temephos flowed at a concentration of 0.05 ppm/10 min, and a third, untreated, gutter as a control. The gutters were positioned one week before the test so that the fauna in them should be well established.

Results obtained in the control gutter

The mean values of the index of drift (ID) were low throughout the day, varying in the range 0-3. They rose slightly from 17h00, with a peak at 17h30 corresponding to the emergence of a species of Orthocladiinae. Subsequently, they remained at a higher level throughout the night, which is a normal phenomenon corresponding to the nocturnal activity period of invertebrates. A clearly defined peak towards 24h00 corresponds to the emergence of Tricorythidae (Ephemeroptera).

Over a period of 24 hours, 258 out of 1492 organisms tested, or 17.29%, went adrift. This value may be regarded as normal, particularly as the test took place during the period of emergence of some of the groups (Orthocladiinae and Tricorythidae).

Results obtained with temephos

The test carried out corresponded to a treatment of the rainy-season type, i.e. at a concentration of 0.05 ppm/10 min.

Treatment was begun at 9h00 and the maximum impact became apparent about an hour later. The maximum increase in drift was 76.56 and the weighted increase was around 50. It is difficult to obtain a precise value, since we had only half an hour of pretreatment drift, during which no organism went adrift! Nevertheless, the values obtained are of the same order of magnitude as those usually obtained by us in similar cases.

The overall percentage detachment over 24 hours was 45.8%, including the natural drift, which we had estimated in the control gutter to be about 17% of the fauna tested.

To determine more precisely the impact of treatment, we therefore have to consider that 17% of the 1227 organisms individually tested, i.e. 208, went adrift "naturally". The remainder (562 - 208 = 354) went adrift through the effect of the poison. This gives a final figure for the drift due to the treatment of the order of 28.8% in 24 hours.

The groups most affected, apart from Baetidae, known to be sensitive, were Tricorythidae, Hydropsychidae and Philopotamidae.

Results obtained with decamethrin

A first treatment was carried out at a concentration of 0.5 ppb/10 min. Having observed the effects for one hour, we applied a second treatment at 5 ppb/10 min. It was immediately apparent that even at concentrations as low as 0.5 ppb, which are never 100% effective against *S. damnosum* s.l., invertebrates are severely affected!

The reaction to treatment at 0.5 ppb/10 min is very violent: Baetidae became detached immediately because of their very exposed location in the natural environment. Other Ephemeroptera (Caenidae, Leptophlebiidae, Tricorythidae) react subsequently and their detachment is at its maximum 30 minutes after the start of treatment.

The maximum increase in ID, which was 68.3, was nearly as great as that obtained with temephos at a concentration of 0.05 ppm (76.6). The weighted increase was 40.5, as against 50 for temephos, confirming the drastic action of decamethrin at such a low concentration.

The second treatment, applied to the system after an hour, at a concentration of 5 ppb/10 min, induced detachment with the same kinetic features but, of course, lower in absolute magnitude because of the large numbers of invertebrates already detached following the first treatment. It may be concluded from the overall results that 1344 of the 1608 organisms tested, or slightly more than 84%, were detached over a period of 24 hours. Allowing for a natural drift level of about 17% over this space of time, it can be calculated that there was "normal" detachment of 273 of the 1608 organisms tested, which brings the number of organisms that were detached through the effect of the treatment to 1071 out of 1608, or about 67% of the total fauna (Table 4).

The extremely violent but short-lasting action of decamethrin suggests that this insecticide has a very marked knock-down effect. The question remained whether this effect might not be of short duration only and whether, after some time, the organisms might not be capable of resuming normal activity. It was to verify this hypothesis that we conducted a series of tests on fish and invertebrates in the river Maroué in the Ivory Coast.

Contamination of test subjects was effected by the use of a fine-mesh landing net to keep them in decamethrin solutions of the desired concentrations for the time required. They were subsequently transferred to storage cages with all possible precautions. Because it was difficult to obtain live material rapidly and in large quantities, we were unable to make large series of tests; nevertheless, our observations cover 62 fish belonging to eight species, and would appear to us to be adequate for conclusions concerning the behaviour of the species tested. Similar tests were conducted on 164 invertebrates drawn from nine taxonomic groups.

In general, the ranges of concentrations tested were at high levels, but, given the short exposure times, they realistically reflect the conditions of airborne release in a vector control campaign. Several litres or decalitres of the product are generally released in zones of relatively calm water upstream from the larval sites to be treated. Diffusion is governed both by the flow rate of the mass of the water and by the morphological features of the river. Under these conditions a concentration of between 10 and 100 ppm in fact persists over a considerable stretch for between a few seconds and a few minutes, and even if the fish are able to move out of the most heavily contaminated zone. In such a case, the shock effect that occurs makes some species lose their balance in a few seconds, prevents them from taking avoiding action and keeps them in contact with the pesticide still longer, which increases their likelihood of being killed. As regard invertebrates, they are incapable in any case of taking avoiding action.

It emerges from our observations that survival time in the knock-down state is variable, probably as a function of the size and condition of the fish and, of course, of the exposure time and the concentration. The first reaction to long exposure and low concentration (1 ppm/10 min, for example) is avoidance, followed by a slackening in activity, "undecided" swimming and an apparent search for oxygen at the surface. The disruption of balance most often occurs at the end of exposure and the balance is restored very rapidly when the fish are returned to uncontaminated water. However, should the balance be disrupted for a second time within four to five hours, death usually results shortly after.

When concentrations are high (50-100 ppm), the shock is very violent and pelagic fish with a high metabolic rate are knocked down in a few seconds (for example, Alestes nurse, which is knocked down by exposure for two seconds at a concentration of 100 ppm). It would appear, moreover, that large fish are knocked down more rapidly than medium-sized fish. Fishes with a slower metabolic rate (Labeo, Tilapia, etc.) have a higher resistance to knock-down, but it is nevertheless undeniable that they are very heavily affected, even if loss of balance does not necessarily manifest itself in the course of contamination.

As regards invertebrates, those exposed to low concentrations for a very brief period are affected and attempt to flee the contaminated zone. In a natural environment, this is manifested in intensive drifting. Their survival rate is low. Furthermore, it would appear that if concentrations increase any injury becomes practically irreversible and leads more or less rapidly to death. From among the organisms tested, only Odonata exhibited a different behaviour pattern; three that we had considered to be close to death three hours after treatment were fully restored after 18 hours. This type of result may be compared with that obtained with large Alestes nurse which, despite an immediate and relatively prolonged loss of balance, gradually resumed what we call a "normal" life within 24 hours.

Finally, it would appear that, under certain treatment conditions, depending on exposure times and concentrations, affected organisms are able to resume normal activity if they survive the many hazards of their drifting in the natural environment.

5. SUMMARY AND DISCUSSION

Some of the trials carried out were designed to enable us to make a realistic appraisal of the possiblities of using microencapsulated insecticides for the control of S. damnosum s.l. larvae in West Africa.

The results obtained are very disappointing in respect both of low effectiveness against blackfly larvae and of high toxicity for the non-target fauna. However, it would seem impossible in the present state of affairs to reach final conclusions on the actual potentialities of this type of formulation. Neither the Reldan nor the Actellic formulations tested corresponded to what would be normally used. The partial effect against blackfly larvae obtained with Reldan may be explained by the deterioration of the microcapsules. Preliminary dry-season trials have shown that a correct Reldan formulation was effective in a river at 0.05 ppm/10 min. The results obtained on the non-target fauna provide very interesting general information on the kinetics of detachment for this formulation, but there are no grounds at all for concluding that a correct formulation is really toxic for the non-target fauna.

The same applies to the tested Actellic microcapsules, the behaviour of which in the river was not at all that initially sought. The working out of that formulation is based on the study of two main factors; on the one hand, the dispersion and behaviour of the microcapsules in the water and, on the other, the optimum rate of release of the active ingredients. The formulation tested in Mali is quite unsuitable for the control of S. damnosum s.l. Changes that would have to be made to this formulation to make it usable could also modify to some extent its toxicity for the non-target fauna. It may be that suitably adjusted formulations will possess lower toxicity than those which have been tested.

The two formulations of K-othrine that we tested possess remarkable larvicidal potency. The effective dose against S. damnosum s.l. would appear to be 0.005 ppm/10 min. The range of the recorded effect when river discharges were low led us to expect that the effective range with higher river discharges would be at least equal to that of Abate. It is, however, of importance to establish in practice whether there is an acceptable compromise between effectiveness against blackfly larvae and toxicity for non-target fauna.

As a whole, our results concerning the action of decamethrin on fish in fact confirm, firstly, that this product is basically highly toxic to fishes. Secondly, it is certain that its use in a blackfly control campaign, even in extremely weak doses (0.003 ppm/10 min, for example) entails a high risk of causing localized mortality among certain species with a high metabolic rate, the more so because mechanical effects causing injury or even death may be added to the toxic effects if the stunned fish are carried into zones of rapids by the current. Although we did not observe any direct mortality in the two experimental treatments carried out in Mali, that does not prove that no fish were killed. Dead fish that sank to the bottom at the point of impact may have been overlooked by us because of the turbidity of the water, or their transportation into the zones of violent rapids where we were working may have removed them from our observation.

As regards the action upon invertebrates, still considering decamethrin, the action kinetics are diametrically opposite, being characterized by an extremely violent and rapid effect which disappeared as quickly as it appeared. Although not ideal, this type of action is more favourable to the maintenance of biological balances in so far as it is possible to control the intensity of the acute effect; on the other hand, the medium-term consequences of the resultant of the partial knock-down yielded by each treatment still has to be verified over a fairly protracted treatment period, both for target and for non-target groups.

We have plotted the different types of detachment kinetics corresponding to these three groups of formulations in Fig. 5. It would appear at the present time that the type of reactions obtained with emulsion concentrates is what we should opt for, in so far as values for maximum instantaneous increase of ID remain at an acceptable level (below 100, for example).

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TABLE 1. RIVER TRIALS OF THE NEW FORMULATIONS: EFFECTS ON BLACKFLY LARVAE

Formulation	Batch	Watercourse	Discharge m^3/s	Dosage ppm/10 min	Effect on blackfly larvae
Reldan[R] 10% of chlorpyrifos-methyl (OMS-1155)	C	Bakoye, below confluence with Baoulé	80	0.05	Partial for 2 km. Imperceptible beyond that.
		Bakoye, Badala ford	44	0.1	Almost completely effective. Only a few late instar larvae remain. No control breeding sites below the ford.
	D	Bakoye, upstream from Toukoto	40	0.075	No apparent effect.
Actellic[R] M20 20% of pirimiphos-methyl (OMS-1424)		Baoulé	22	0.075	Very partial effect for 7 km following verification after 24 and 48 hours.
		Bakoye, below Badala ford	44	0.1	Partial effect on the first breeding site after 24 and 48 hours, imperceptible below.
K-othrine[R] 2.5% of decamethrin (OMS-1998)	A	Darouma, tributary of Bakoye	6.3	0.02	Completely effective over the 12 km accessible above confluence with Bakoye. Range in excess of 12 km.
	B	Badinn-ko, tributary of Bakoye	7	0.007	Completely effective over 10 km. Partial effect at 11.5 km after 1.5 km of slack water.
		Baoulé	16.6	0.003	Partial effect. Late instar larvae remain.
		Baoulé	16.6	0.001	Detachment of early instars.

TABLE 2. OVERALL RESULTS OF THE GUTTER TEST OF THE TOXICITY OF RELDAN C

Taxa	Drifting fauna	Fauna remaining at end of experiment	Total fauna tested	Percentage detachment
Baetidae	258	2	260	99.2
Caenidae	2	0	2	100
Tricorythidae	8	24	32	25
Oligoneuridae	1	45	46	2.2
Heptageniidae	0	1	1	0
S. damnosum	263	293	556	47.3
Other Simuliidae	343	323	666	51.5
Orthocladiinae	173	53	226	76.5
Chironomini	71	14	85	83.5
Tanytarsini	9	6	15	60
Tanypodinae	5	1	6	83.3
Ceratopogonidae	0	2	2	0
T 1	48	34	82	58.5
T 11	3	0	3	100
T 14	47	32	79	59.5
T 16	0	6	6	0
T 20	164	2	166	98.8
Dytiscidae	3	0	3	100
Elmidae	2	2	4	50
Gerridae	6	0	6	100
Sisyridae	9	2	11	81.8
Veliidae	6	0	6	100
Libellulidae	1	0	1	100
Oligochaeta	6	0	6	100
Hydracarina	7	0	7	100
Nematoda	4	1	5	80
Plecoptera	1	0	1	100
Total	1 440	843	2 283	Global percentage : 63.07

TABLE 3. DRIFT RECORDED IN GUTTER OVER A 12-HOUR OBSERVATION PERIOD FOLLOWING THE PASSAGE OF ACTELLIC M20

Taxa	Drifting fauna	Fauna remaining	Total fauna tested	Percentage detachment
Baetidae	319	16	335	95.2
Caenidae	4	0	4	100
Leptophlebiidae	9	0	9	100
Tricorythidae	27	2	29	93.1
Oligoneuridae	3	4	7	42.9
Heptageniidae	3	0	3	100
S. damnosum	93	434	527	17.6
Other Simuliidae	364	2 925	3 289	11.1
Orthocladiinae	60	154	214	28.0
Chironomini	97	55	152	63.8
Tanytarsini	14	25	39	35.9
Tanypodinae	7	35	42	12.2
T 1	37	98	135	27.4
T 10	15	21	36	41.7
T 11	1	2	3	33.3
T 14	6	121	127	4.7
T 16	35	125	160	21.9
T 20	0	1	1	0
T 22	1	1	2	50
Dytiscidae	2	5	7	28.6
Hydrophilidae	1	9	10	100
Agrionidae	1	0	1	100
Libellulidae	0	3	3	0
Sisyridae	1	0	1	100
Pyralidae	0	1	1	0
Rhagionidae	0	7	7	0
Ceratopogonidae	0	19	19	0
Micronecta	0	2	2	0
Oligochaeta	0	9	9	0
Hydracarina	2	0	2	100
Total	1 102	4 074	5 176	21.29

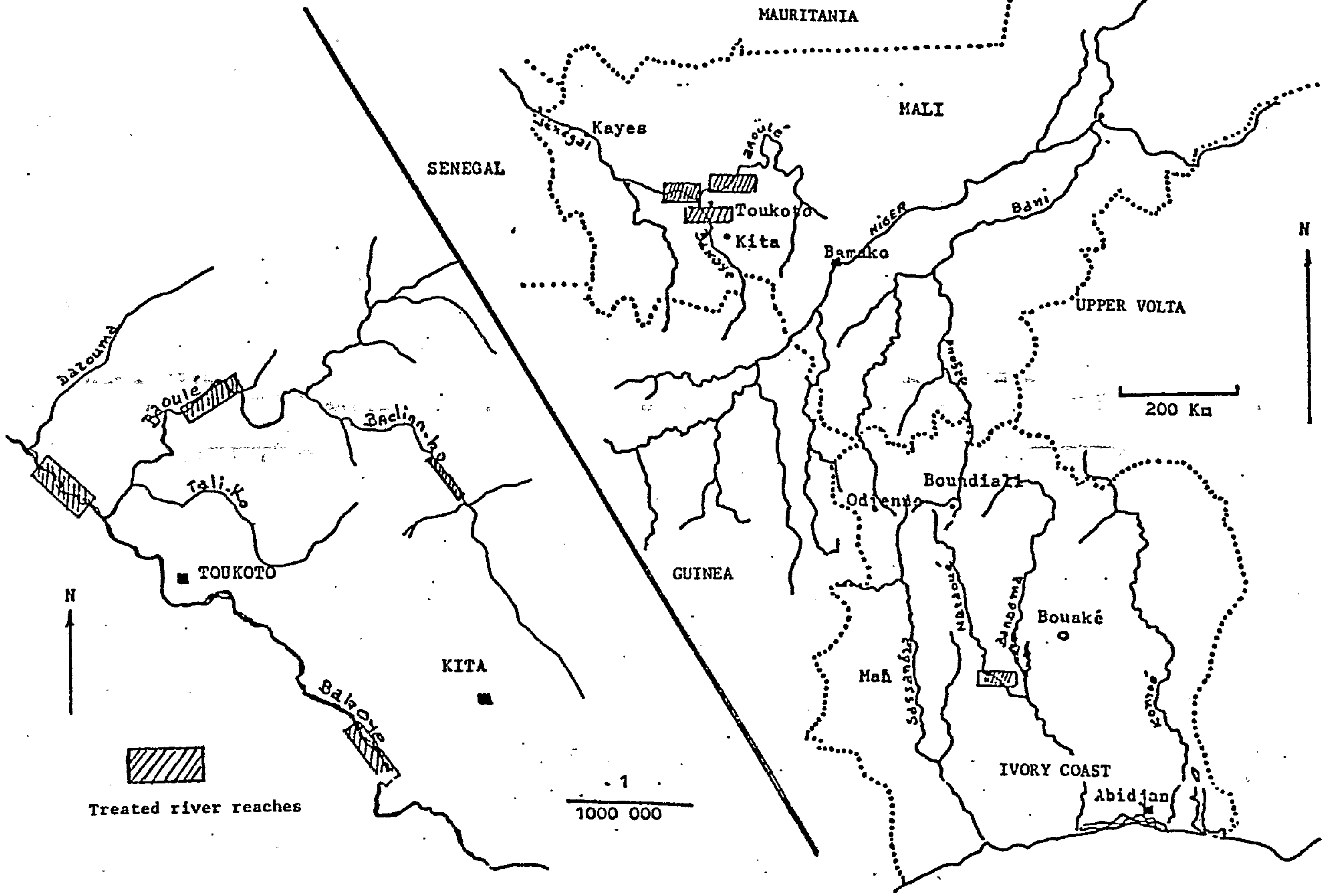
TABLE 4. COMPARISON OF PERCENTAGE DETACHMENT OF VARIOUS TAXONOMIC GROUPS OVER A PERIOD OF 24 HOURS IN RELATION TO THE INSECTICIDES TESTED*

Taxa	Percentage detachment in the control gutter	Percentage detachment with temephos at 0.05 ppm/10 min	Percentage detachment with decamethrin at 0.5 and then 5 ppb/10 min
Baetidae	22.58	58.68	94.74
Caenidae	9.62	2.94	95.17
Leptophlebiidae	4.26	48.88	93.91
Tricorythidae	20.52	77.73	96.63
Ephemeridae	0	0	100.00
Oligoneuridae	0	0	76.51
Heptageniidae	3.77	16.66	100.00
Chironomini	44.44	72.00	77.83
Tanytarsini	0	20.00	100.00
Orthocladiinae	67.24	62.71	75.00
Tanypodiinae	10.20	25.00	76.00
Ceratopogonidae	100.00	50.00	0
Simuliidae	12.65	22.17	63.20
Tipulidae	-	-	100.00
T 1	20.73	42.01	55.20
T 2	0	100.00	100.00
T 10	0	75.00	87.54
T 16	3.67	61.19	82.33
T 32	100.00	100.00	100.00
T 14	-	50.00	71.42
Hydrophilidae	0	16.66	0
T 20	0	-	100.00
Dytiscidae	100.00		100.00
Elmidae	50.00	33.33	63.61
<u>Neoperla</u>	0	0	100.00
Gomphidae	0	0	-
Libellulidae	0	33.33	100.00
Hydrachnellae	33.33	50.00	100.00
Rhagionidae	0	10.66	0
Gasteropode	0	0	0
Veliidae	0		0
Gerridae	100.00	-	-
Agrionidae			14.33
Global percentage detachment	17.29	45.80	84.07
Total number of organisms tested	1 750	2 089	1 608

* 0 signifies that organisms belonging to this group were tested, but that there was no drift;

\- signifies that no organism of this group was present in the fauna tested.

FIG. 1. MAP SHOWING LOCATION OF TREATMENT ZONES



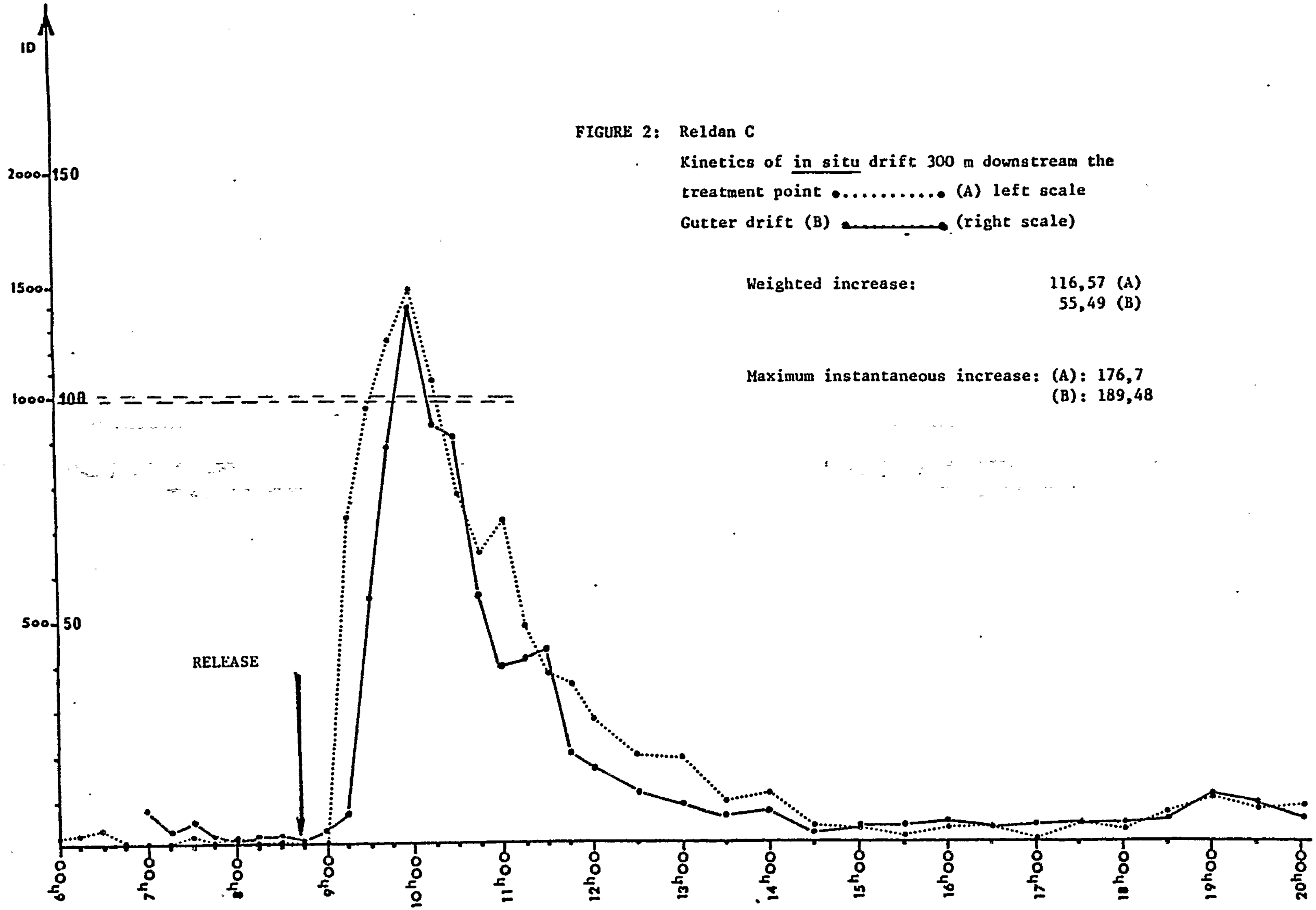


FIGURE 2: Reldan C

Kinetics of <u>in situ</u> drift 300 m downstream the treatment point •.........• (A) left scale

Gutter drift (B) •————• (right scale)

Weighted increase: 116,57 (A)
55,49 (B)

Maximum instantaneous increase: (A): 176,7
(B): 189,48

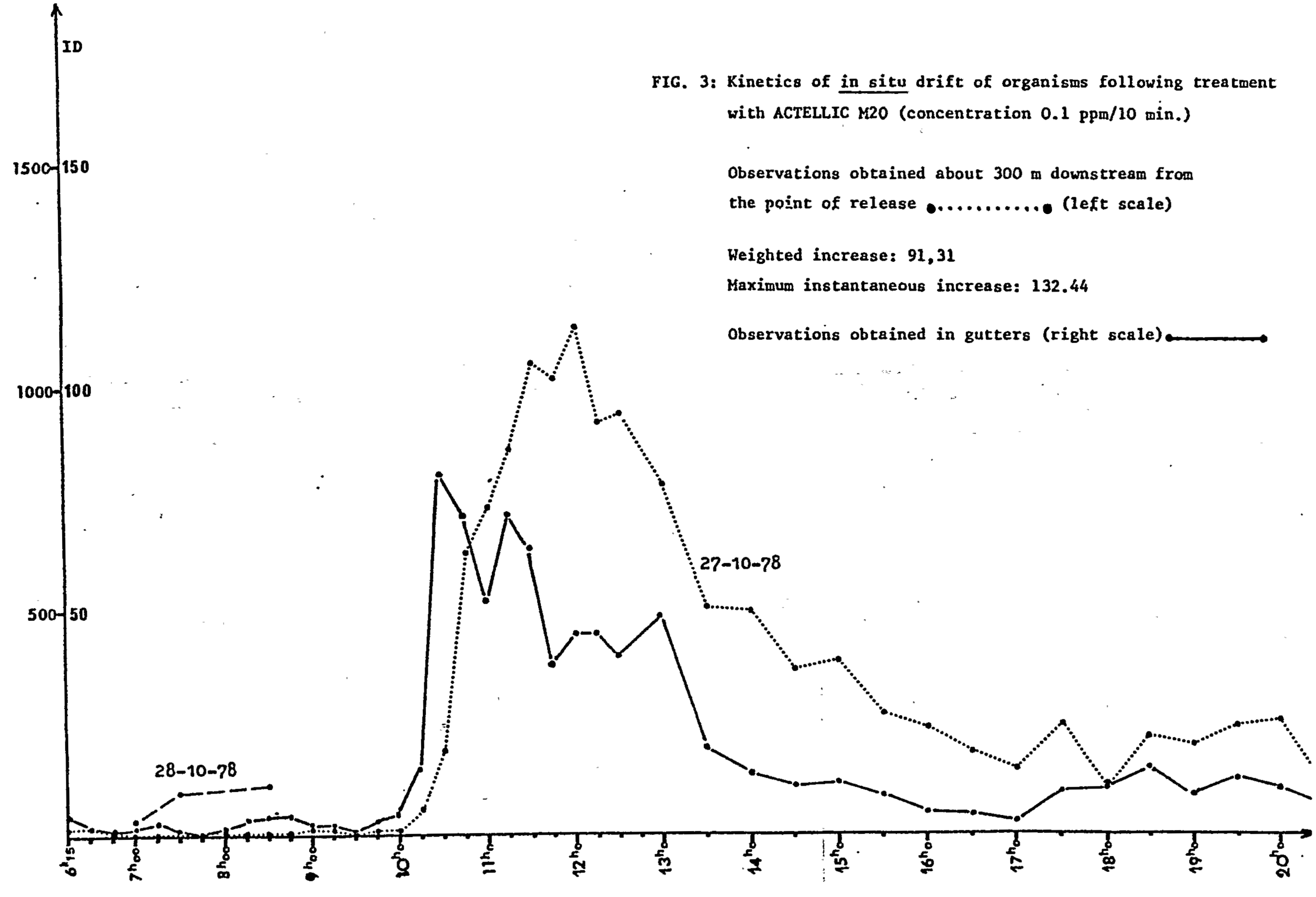


FIG. 3: Kinetics of <u>in situ</u> drift of organisms following treatment with ACTELLIC M20 (concentration 0.1 ppm/10 min.)

Observations obtained about 300 m downstream from the point of release •...........• (left scale)

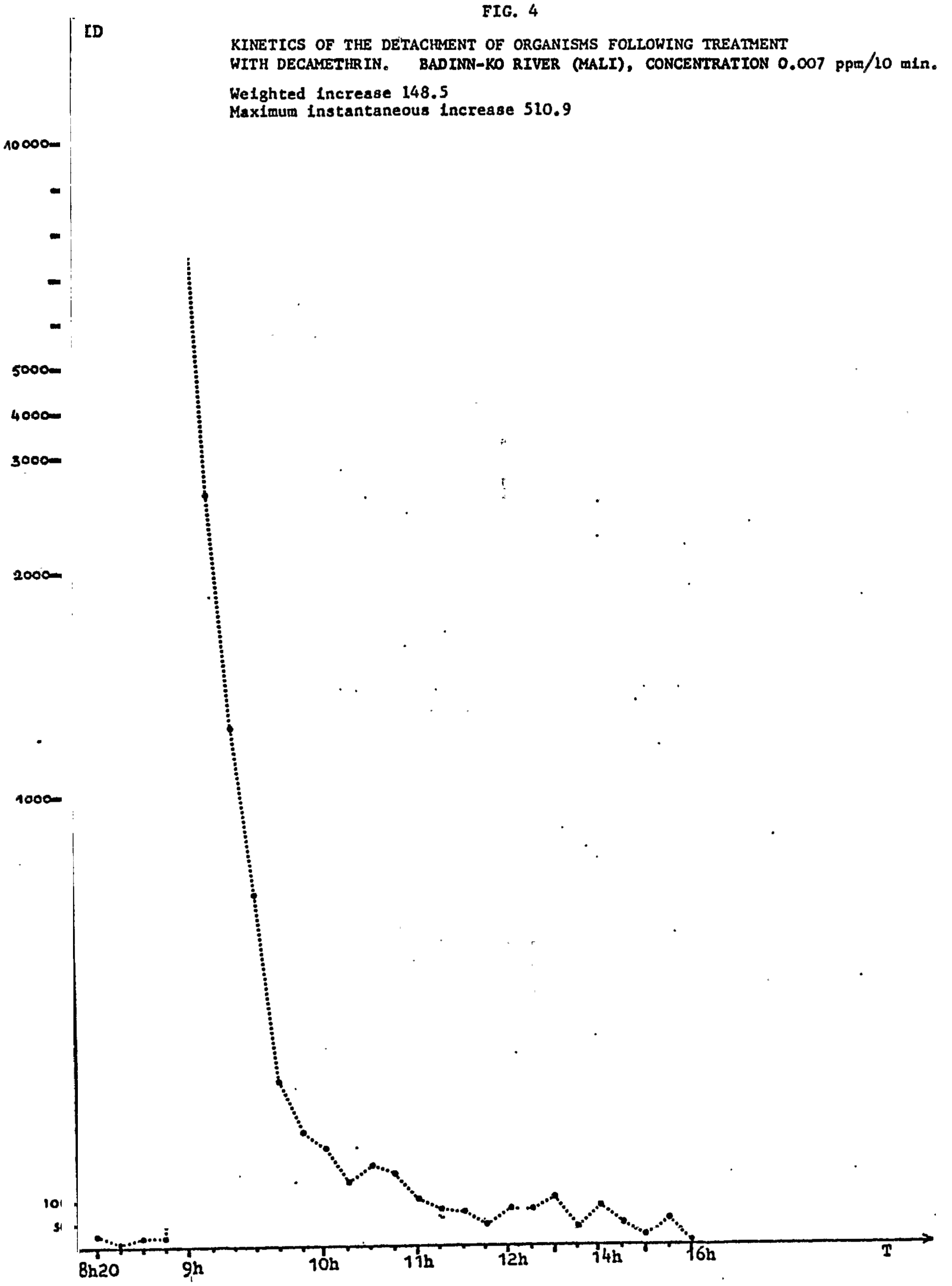
Weighted increase: 91,31
Maximum instantaneous increase: 132.44

Observations obtained in gutters (right scale) •————•

FIG. 4

KINETICS OF THE DETACHMENT OF ORGANISMS FOLLOWING TREATMENT WITH DECAMETHRIN. BADINN-KO RIVER (MALI), CONCENTRATION 0.007 ppm/10 min.

Weighted increase 148.5
Maximum instantaneous increase 510.9



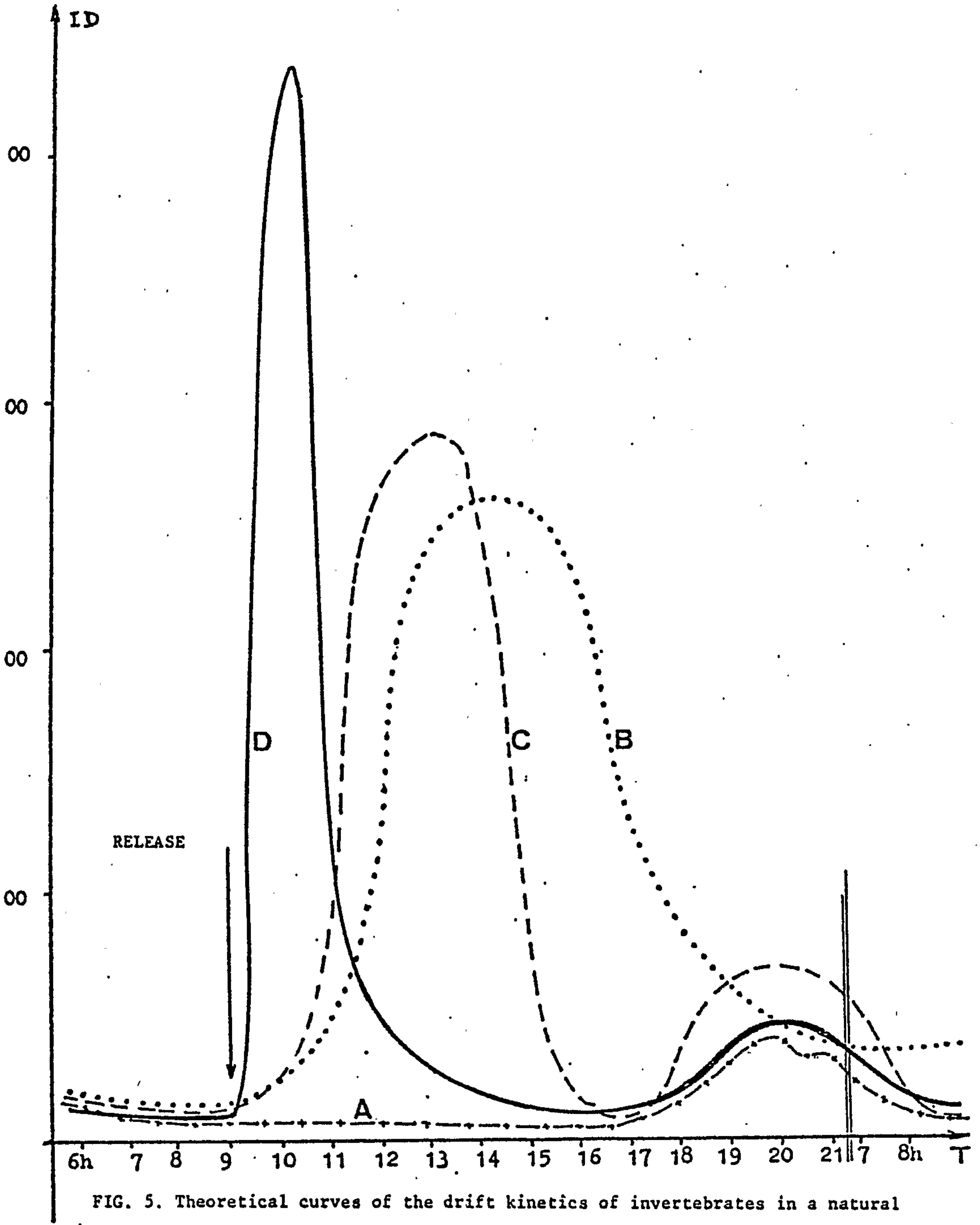


FIG. 5. Theoretical curves of the drift kinetics of invertebrates in a natural environment

A. in the absence of pesticide;

B. on release of a microencapsulated formulation;

C. on release of an emulsion concentrate:

D. on release of a pyrethroid.