

# The efficacy of various pyrethroid insecticides for use on odour-baited targets to control tsetse

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**Abstract.** The efficacy of various pyrethroid insecticides for use on odour-baited targets to control tsetse was compared in Zimbabwe. Formulations were applied to cotton cloth and polyester net and, at various intervals, the materials were bio-assayed by exposing fed female *Glossina pallidipes* (Austen) (Diptera: Glossinidae) to cloth for 45 s or by inducing them to collide briefly with net. Trial formulations were compared with deltamethrin suspension concentrate (s.c.), the insecticide currently used in tsetse control operations in Zimbabwe. Applying 0.8% suspension of alphacypermethrin to cloth or net produced high mortalities for 9 months which was similar in performance to 0.4% suspension of deltamethrin s.c. Deltamethrin s.c. and  $\beta$ -cyfluthrin s.c. applied to cloth as 0.1% suspensions were equally effective, producing high mortalities for 2 months during the wet season, and 0.8% suspension of  $\beta$ -cyfluthrin was effective for 12 months. Suspensions of 0.1% lambdacyhalothrin capsule suspension or 0.1% lambdacyhalothrin wettable powder were significantly less effective than 0.1% deltamethrin s.c. Chemical analyses showed that increasing the concentration of insecticide applied to material increased the initial amount of insecticide on the material and decreased the subsequent rate of loss; 0.1% suspension of  $\beta$ -cyfluthrin s.c. applied to cloth produced an initial concentration of  $\approx 280 \text{ mg/m}^2$  which declined by 94% in 12 months whereas 0.8% suspension showed no significant decrease in concentration (mean =  $1304 \text{ mg/m}^2$ ) over the same period. For controlling tsetse by means of pyrethroid-treated targets, it is suggested that  $\beta$ -cyfluthrin s.c. is as effective as deltamethrin s.c. but that alphacypermethrin s.c. should be used at twice the concentration of deltamethrin s.c. to obtain the same performance.

**Key words.** *Glossina*, alphacypermethrin,  $\beta$ -cyfluthrin, deltamethrin, insecticide, lambdacyhalothrin, pyrethroid, targets, tsetse, Zimbabwe.

## Introduction

Bait technology, consisting of either insecticide-treated targets or traps baited with synthetic or semi-synthetic odours, or insecticide-treated cattle, has become the most common method of controlling tsetse (Diptera: Glossinidae) across Africa (Green, 1994). In Zimbabwe for instance, targets baited with a blend of synthetic host odours were first used on a large-scale trial in 1984 in an area of  $600 \text{ km}^2$  in the Zambezi Valley

(Vale *et al.*, 1988). In that year, control operations carried out elsewhere in Zimbabwe also included  $7400 \text{ km}^2$  of territory treated by ground-spraying operations with DDT and a further  $1700 \text{ km}^2$  treated by the aerial application of endosulfan (Vale, 1993). In 1998, by contrast, only bait technology is in use and tsetse are currently being controlled by  $\approx 50\,000$  odour-baited targets and the insecticidal treatment of  $\approx 50\,000$  cattle only (V. Chadenga, personal communication).

The increasing use of insecticide-treated targets throughout Africa is a result of the technique's efficacy (Vale *et al.*, 1988; Willemse, 1991; Green, 1994), its relatively low cost (Barrett, 1994), the amenability of the technique for use by communities

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and individuals (Green, 1994) and its unique ability to protect areas cleared of tsetse from reinvasion by tsetse in adjacent infested areas (Vale *et al.*, 1988; Hargrove, 1993).

The performance of the insecticide applied to targets is an important component of the success of the technique. The insecticide formulations applied to targets used in the 1980s were generally less effective during the wet season (Laveissière *et al.*, 1985; Torr, 1985; Torr *et al.*, 1992). Moreover, the labour and transport costs of visiting targets at 3-month intervals to replenish the odour attractants and respray the target with insecticide (Vale *et al.*, 1988) accounted for half the cost of the technique (Barrett, 1994). Accordingly, Torr *et al.* (1992) showed that spraying targets with 0.6% deltamethrin suspension concentrate (s.c.) produced high mortalities for at least 1 year and Torr *et al.* (1997) developed methods for dispensing attractants that were effective for >12 months. These developments have resulted in substantial improvements in the cost-effectiveness of the technique.

As a consequence of these insecticide studies which demonstrated the effectiveness of deltamethrin, tsetse control operations in Zimbabwe and elsewhere in the region have become reliant on using deltamethrin suspension concentrate supplied by a single manufacturer. The present paper describes work to identify alternative insecticide formulations that were at least as effective as deltamethrin s.c.

## Materials and Methods

All experiments were undertaken between 1986 and 1994 at Rekomitjie Research Station in the Zambezi Valley of Zimbabwe where *Glossina pallidipes* (Austen) is present.

### Insecticides

Four different pyrethroids were compared. Deltamethrin was provided by Ecomark (Pvt) Ltd, Zimbabwe, as a 20% weight/volume (w/v) suspension concentrate (s.c.) (Glossinex<sup>®</sup>),  $\beta$ -cyfluthrin was provided by Bayer (Zimbabwe) as a 12.5% w/v s.c. (Responsar<sup>®</sup>), alphacypermethrin was provided by Shell (Zimbabwe) as a 1.5%, 6% or 25% w/v s.c. (Fastac<sup>®</sup>) and lambda-cyhalothrin (Icon<sup>®</sup>) was supplied by ICI (U.K.) as either 10% weight/weight (w/w) wettable powder (w.p.) or 10% w/v capsule suspension (c.s.).

### Target materials

Targets used in control operations consist of either a panel of cotton cloth or a panel of cotton flanked by panels of fine black netting (Vale *et al.*, 1988; Vale, 1993; Green, 1994). The cloth and netting are impregnated with insecticide and tsetse pick up insecticide by either alighting on the cotton panel or colliding with the netting panels which are effectively invisible to tsetse (Vale, 1974; Griffiths & Brady, 1994). For much of the 1980s, targets in Zimbabwe had netting panels but more recently these have been changed to all-cloth targets; either

completely black or with the central black panel flanked by blue panels (Vale, 1993). In the latter, tsetse alight on the black portion of the target (Vale, 1993) and it is only this section of the target that is treated with insecticide.

In the present investigation, studies were made of the performance of insecticides applied to black cotton drill cloth (Ref. 20201) and textured yarn, black polyester net, both supplied by Bonar Industries (Zimbabwe). These materials have been used in tsetse control operations in Botswana, Malawi, Zambia and Zimbabwe.

The materials were treated by immersion in an aqueous suspension of insecticide and then left to dry. In some experiments, samples of freshly treated material were sealed in aluminium foil envelopes and sent to laboratories at the Natural Resources Institute for chemical analysis by gas chromatography to determine the amount of insecticide.

### Weathering

Treated samples of net and cloth were exposed to direct sunlight and rain for various intervals. The materials were suspended vertically from wire supports in an open area (10 × 5 m) within the grounds of Rekomitjie Research Station. There were no trees or bushes within 100 m of the site and, as such, the materials were fully exposed to sunlight and rain. Rainfall was recorded daily from the Rekomitjie meteorological station located ≈ 200 m from the materials. At various intervals, samples of cloth (30 × 20 cm) and net (10 × 13 cm) were taken for bioassay and chemical analysis.

### Bioassays

Adult females of *G. pallidipes* from the wild population at Rekomitjie Research Station were used in all bioassays. Tsetse were caught in the late afternoon after they had fed from a bait ox. The tsetse were retained singly in a glass tube (2.5 cm × 7.5 cm) with a cork stopper at one end and netting at the other. Captured tsetse were kept in a polystyrene cool box and later transferred to an insectary at 23–25°C, 60–70% r.h.

Bioassays were undertaken on the morning after the tsetse were collected. Insecticide deposits on cloth were bioassayed following the technique described by Pilsen (1968). Ten subsamples of the treated cloth were mounted on lengths of doweling (19 mm dia.). These were inserted singly into the tubes containing the tsetse and each tsetse was allowed to rest on the material for 45 s.

Net was bioassayed following the technique developed by Torr (1985). A sample of treated net was placed in front of a light source within a flight chamber. Tsetse were introduced into the chamber singly and as they flew towards the light they collided briefly (< 1 s) with the net before being diverted to a retaining tube. Tsetse landing on the netting were discarded and excluded from the assay.

At least thirty tsetse were exposed in each treatment and control tsetse were exposed in the same manner to untreated materials. After treatment, tsetse were returned to the insectary

and held there for 72 h after which time mortalities were recorded and corrected for control mortalities using Abbott's formula (Busvine, 1971); mean control mortality was 1%.

### Chemical analyses

Samples of material ( $\approx 100\text{--}300\text{ cm}^2$ ) were inserted into a soxhlet chamber and extracted for 4 h with hexane and then made up to a final volume of  $50\text{ cm}^3$ . Analyses were performed with a Carlo Erba Model 4300 gas chromatograph (GC) equipped with a glass column ( $1000\text{ mm} \times 3\text{ mm i.d.}$ ) packed with 3% OV225 on Chrom W-HP (80–100 mesh). The carrier gas was nitrogen and the flow rate was 40 ml/min. Oven temperature was  $240^\circ\text{C}$ , injector temperature was  $260^\circ\text{C}$  and the flame ionization detector temperature was  $300^\circ\text{C}$ . The injection volume was  $5\text{ }\mu\text{l}$ .

### Statistics

All experiments were analysed using GLIM4 (Francis *et al.*, 1993) which fits models using a maximum likelihood method. To assess the significance of differences in the mortalities produced by different insecticide formulations a binomial model with a logit link was specified. The significance of changes in deviance were assessed by  $\chi^2$  or by an *F*-test after rescaling if the data displayed over dispersion (Crawley, 1993). To analyse changes in the amount of insecticide with time, a normal model was specified, the concentrations ( $\text{mg/m}^2$ ) were transformed to  $\text{Log}_{10}(\text{mg/m}^2)$  and the data subjected to regression analysis with the age of the deposit(s) as the independent variable. The term 'significant' indicates that treatments differed at the  $P < 0.05$  level of probability at least.

## Results

Previous results have indicated that the effective life of various insecticides is reduced significantly during the wet season (Torr, 1985; Torr *et al.*, 1992) and thus most experiments were conducted during the wet season (November to March). The total seasonal rainfall for all years during which insecticide studies were undertaken ranged between 460 mm and 828 mm (Table 1). In 1991–

**Table 1.** Monthly rainfall for October to April for years during which studies of insecticide performance were undertaken.

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
1986–87	53	51	214	222	15	4	0	559
1990–91	0	44	125	209	53	62	38	530
1991–92	10	86	97	132	39	76	21	460
1992–93	2	32	272	73	326	69	54	828
1993–94	0	89	70	215	52	51	1	478

92, there was an exceptionally severe and widespread drought throughout southern Africa and the rainfall figures for Rekomitjie reflect this.

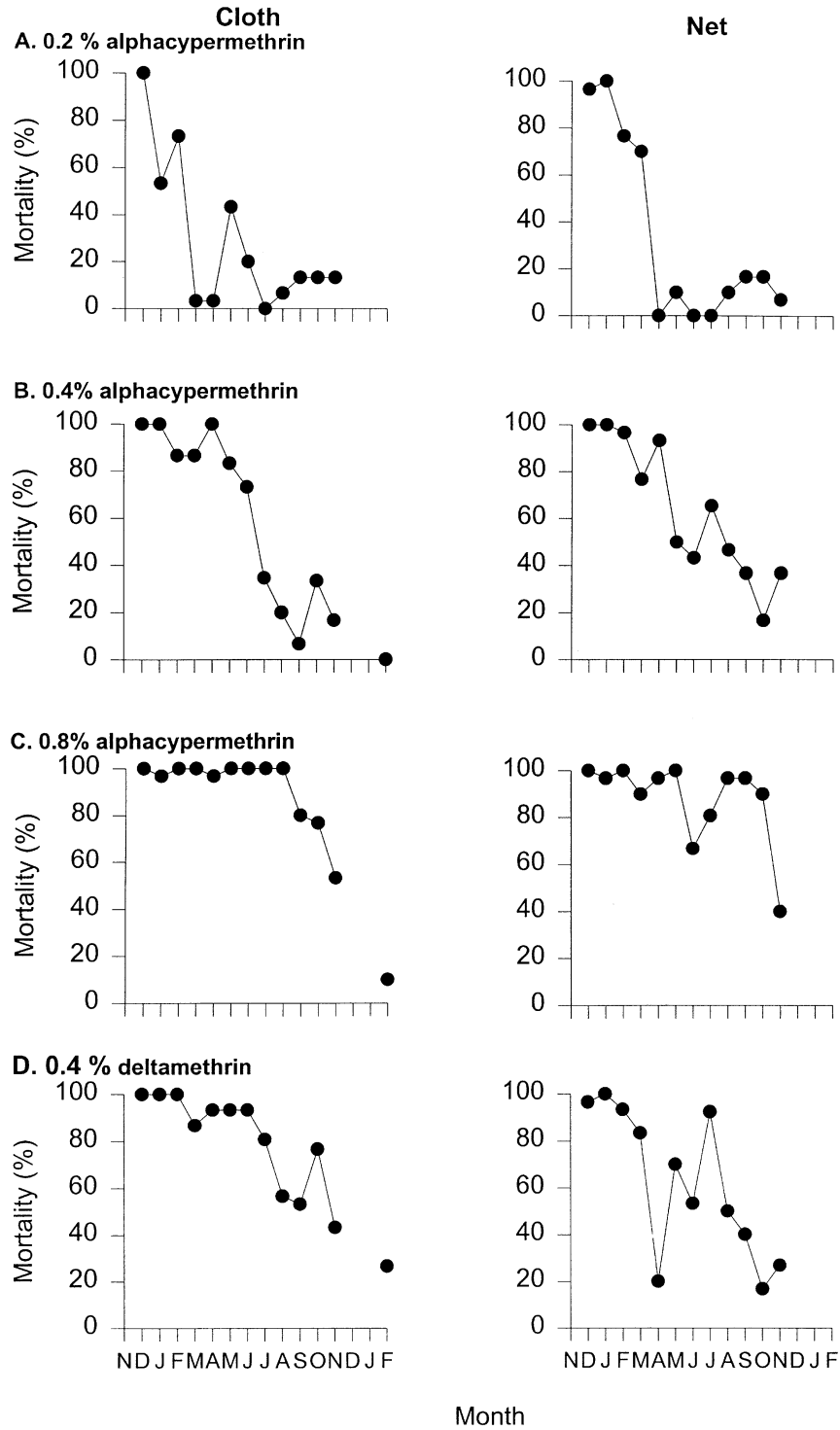
### Alphacypermethrin

Preliminary studies were made of the performance of alphacypermethrin in 1986–87 and various formulations were compared with cloth and net treated with 0.1% deltamethrin s.c.; the results for the deltamethrin treatments have been reported in a previous paper (Torr *et al.*, 1992). The results for alphacypermethrin (Table 2) show that treating cloth with a 0.2% suspension produced high (>90%) mortalities for 150 days during the dry season. During the wet season, cloth and net were treated with various concentrations of alphacypermethrin and none produced mortalities >55% after 90 days. These results are similar to those for deltamethrin tested during the same season (Torr *et al.*, 1992) and suggested that alphacypermethrin might be an effective alternative to deltamethrin.

Accordingly, a second study was initiated in November 1990 with 25% alphacypermethrin s.c. applied to cloth or net at concentrations of 0.2–0.8%. These treatments were compared with cloth and net treated with 0.4% deltamethrin s.c.; this being the concentration of deltamethrin used in routine control operations in Zimbabwe at that time. The results (Fig. 1) show that increasing the concentration of alphacypermethrin increased the effective life of the insecti-

**Table 2.** Percentage mortality of *G. pallidipes* females exposed to net and cotton cloth treated with various formulations of alphacypermethrin s.c. Studies were undertaken during the 1986–87 wet season and the 1987 dry season. No studies were made of cloth during the dry season.

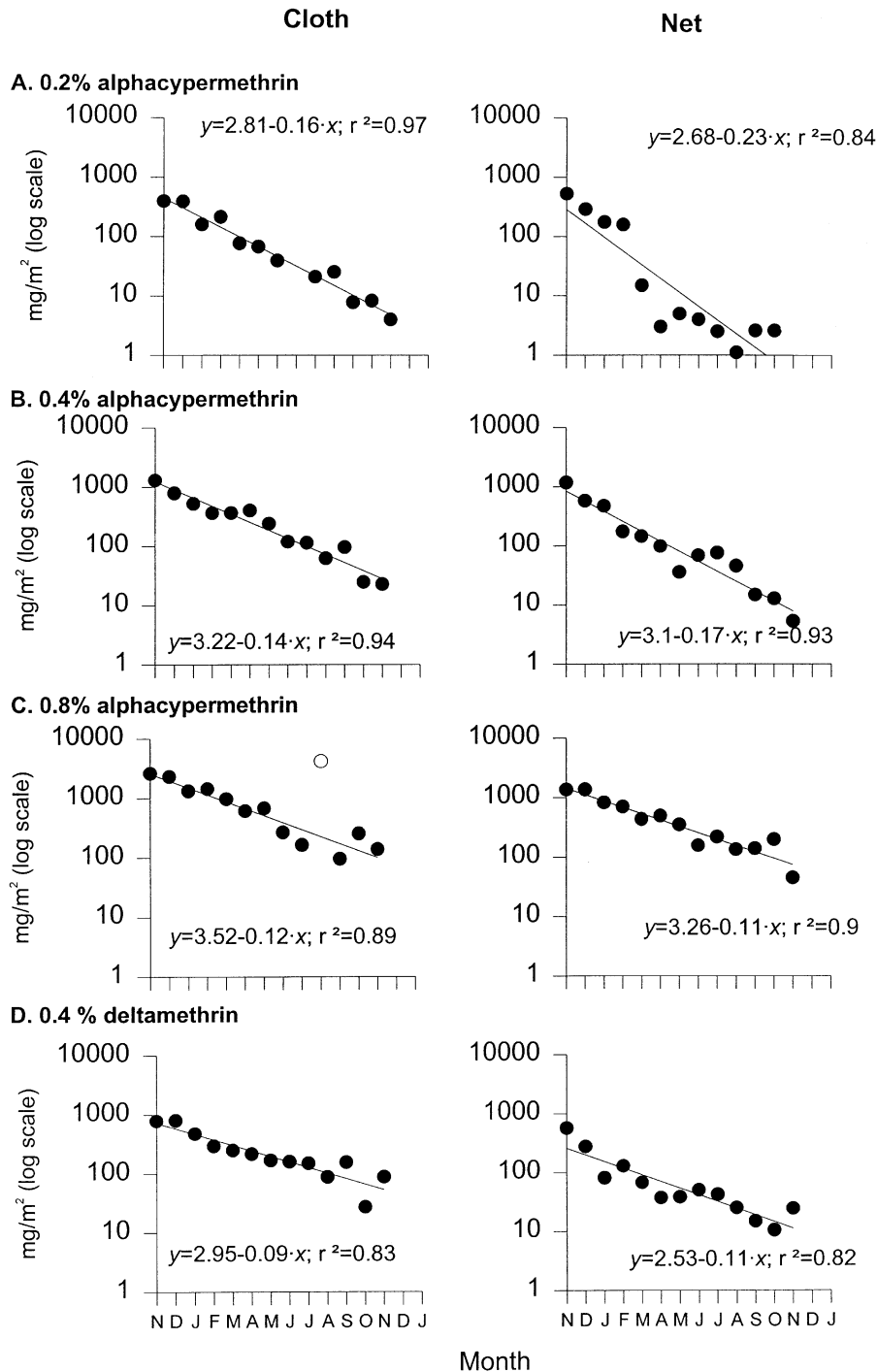
Formulation % a.i.	Mortality (%) at day						
	0	30	60	90	120	150	180
Net – wet season							
25% s.c.	0.1	97	97	17	3	–	–
	0.05	97	97	7	0	–	–
6% s.c.	0.12	93	83	13	10	7	–
	0.06	93	13	7	0	–	–
	0.03	97	7	3	3	0	–
1.5% s.c.	0.1	83	13	3	0	–	–
	0.05	80	19	7	0	–	–
Cloth – wet season							
25% s.c.	0.1	100	97	7	23	12	–
	0.05	96	3	3	0	–	–
6% s.c.	0.12	100	57	17	0	–	–
	0.06	100	80	83	3	5	–
	0.03	100	70	30	3	2	–
1.5% s.c.	0.1	97	100	87	53	12	–
	0.05	100	80	50	13	5	–
Net – dry season							
25% s.c.	0.2	97	97	90	96	93	97



**Fig. 1.** Percentage mortality of *G. pallidipes* females exposed to cloth or net treated with various concentrations of alphacypermethrin suspension concentrate (s.c.) or deltamethrin s.c. and weathered for various periods. The trial commenced in November 1990.

cide. Mortalities were <80% after only 2 months for materials treated with 0.2% alphacypermethrin compared to 4 months for 0.4% alphacypermethrin and 9 months for 0.8% alphacyper-

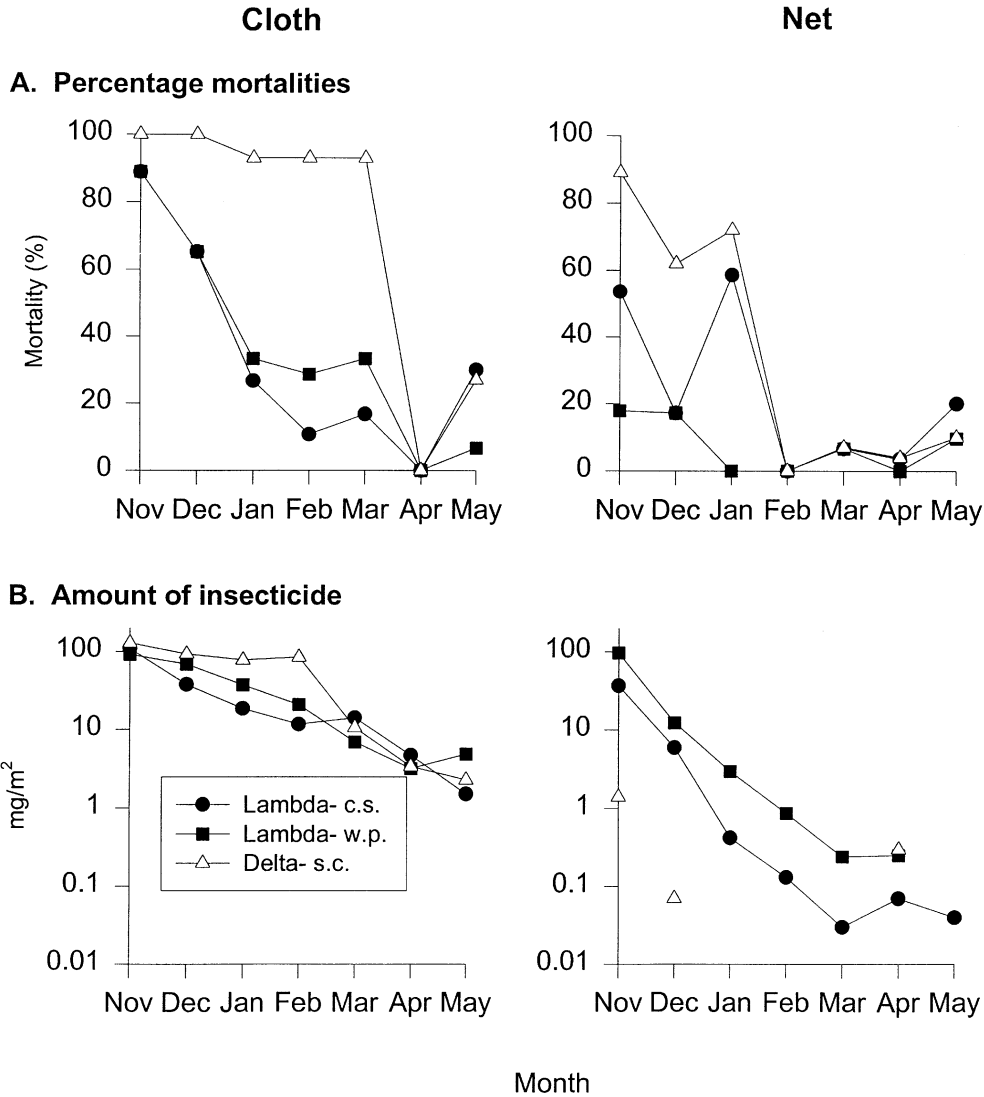
methrin. Materials treated with 0.4% deltamethrin produced mortalities <80% after 8 months for cloth and 4 months for net which is similar to the results previously reported for 0.4%



**Fig. 2.** Amount of insecticide on cloth or net treated with various concentrations of alphacypermethrin suspension concentrate (s.c.) or deltamethrin s.c. and weathered for various periods. The trial commenced in November 1990. Lines fitted by regression analysis following Log<sub>10</sub> transformation of insecticide amounts (mg/m<sup>2</sup>) and with age in months as independent variable (x). Open circle in figure C (0.8% alphacypermethrin on cloth) was not included in the regression analysis.

deltamethrin s.c. applied to cloth and net (Torr *et al.*, 1992). The present results suggest that the 0.4% deltamethrin s.c. is similar in performance to the 0.8% formulation of alphacypermethrin.

Chemical analysis of the materials (Fig. 2) showed that significantly more insecticide was retained on the cloth than net and, in general, the amount of insecticide on the cloth and net increased significantly as the concentration of



**Fig. 3.** Percentage mortalities (A) of female *G. pallidipes* exposed to cloth or net treated with various concentrations of lambdacyhalothrin wettable powder or capsule suspension or deltamethrin suspension concentrate and weathered for various periods and (B) the amount of insecticide on the materials. The trial commenced in October 1992.

insecticide increased and decreased significantly with time. However, the exception to this trend was a single data point for 0.8% alphacypermethrin on cloth (Fig. 2C) where the amount of insecticide measured after 10 months of exposure (4160 mg/m<sup>2</sup>) was substantially greater than any of the preceding measurements, including that measured after just 1 month of exposure (2600 mg/m<sup>2</sup>). Regression analysis of these particular data showed that when the anomalous data point was included, time of exposure explained just 50% of the variance compared to 89% without this data point, and the regression coefficients with or without the data point were -0.10 and -0.12, respectively (Fig. 2C).

The results of the regression analyses (Fig. 2) show that the regression coefficients (*b*) varied significantly between treat-

ments with the rate of decline being lower for treatments with higher initial concentrations. The rate of loss of alphacypermethrin was slightly, but significantly, greater than that for deltamethrin when both formulations were applied at comparable concentrations (0.4%) on cloth ( $F_{1,23} = 6.6$ ;  $P < 0.05$  for difference between slopes) or net ( $F_{1,23} = 6.8$ ;  $P < 0.05$ ).

*Lambdacyhalothrin*

Cloth and net were treated with 0.1% suspensions of lambdacyhalothrin w.p. and c.s. and compared with 0.1% deltamethrin s.c. over the 1992-93 wet season during which 828 mm of rain fell (Table 1). The results (Fig. 3) show that deposits of lambdacyhalothrin on cloth produced mortalities <70% after 2 months exposure, whereas the deltamethrin

formulation produced mortalities >90% for 5 months. For net, deltamethrin produced consistently higher mortalities than either lambda-dacyhalothrin formulation but the mortalities for all three formulations were <30% after 3 months of exposure. Chemical analyses of samples of cloth that had been exposed for 30 days showed that the amounts of lambda-dacyhalothrin c.s. and lambda-dacyhalothrin w.p. and deltamethrin s.c. on cloth were 96 mg/m<sup>2</sup>, 93 mg/m<sup>2</sup> and 123 mg/m<sup>2</sup> compared to 20 mg/m<sup>2</sup>, 46 mg/m<sup>2</sup> and 81 mg/m<sup>2</sup>, respectively, 90 days after treatment. Thus, the poor performance of the lambda-dacyhalothrin-treated cloth appears to be due, at least in part, to the rapid loss of active ingredient during the wet season.

In the trial of lambda-dacyhalothrin, the rate of loss of deltamethrin exhibited a marked discontinuity in February/March. This is in contrast to previous (Torr *et al.*, 1992) and present studies of the rate of loss of pyrethroids with time which generally show a smooth exponential decline in concentration with time. The unusual decline of deltamethrin in the lambda-dacyhalothrin trial may have been due to the exceptionally heavy rainfall in February 1992 when 326 mm of rain fell (see Table 1).

#### *β-cyfluthrin*

Materials treated with either *β*-cyfluthrin s.c. (0.1–0.8%) or 0.1% deltamethrin s.c. were compared. Samples were treated in October 1993 and bioassayed at approximately monthly intervals until November 1994. Only insecticide deposits on cloth were studied since by 1993 the targets with netting panels were no longer being used in Zimbabwe.

The bioassay results (Fig. 4) show that there was no significant difference in the performance of 0.1% suspensions of deltamethrin and *β*-cyfluthrin with both producing mortalities which declined to <80% within ≈2 months during the wet season. Applying *β*-cyfluthrin at 0.2%, 0.4% and 0.8% increased the effective life (mortalities >80%) of the deposit to 3, 8 months and 12 months, respectively.

The chemical analyses showed that cloth treated with 0.1% deltamethrin was found to have significantly more insecticide than cloth treated with the same concentration of *β*-cyfluthrin; the intercepts for the deltamethrin and *β*-cyfluthrin regression equations indicate that the initial amounts of insecticide on the cloth were 501 mg/m<sup>2</sup> and 281 mg/m<sup>2</sup>, respectively (Fig. 4). There was no significant difference in the rate of loss of the two insecticides.

Increasing the concentration of the suspensions of *β*-cyfluthrin applied to the cloth generally increased the amount of insecticide on the cloth, as expected, and decreased the proportional rate of loss of insecticide with time. For the highest concentration tested (0.8%), there was no significant loss of insecticide over the 12-month period of investigation and the mean concentration over the 12-month period was 1304 mg/m<sup>2</sup>.

#### Discussion

The present results suggest that *β*-cyfluthrin s.c. is as effective as deltamethrin s.c.; the performances of the two insecticides at comparable concentrations were not significantly different and the rates of loss of insecticide were also similar. Thus, the

present results indicate that this insecticide formulation is an effective alternative to deltamethrin s.c.

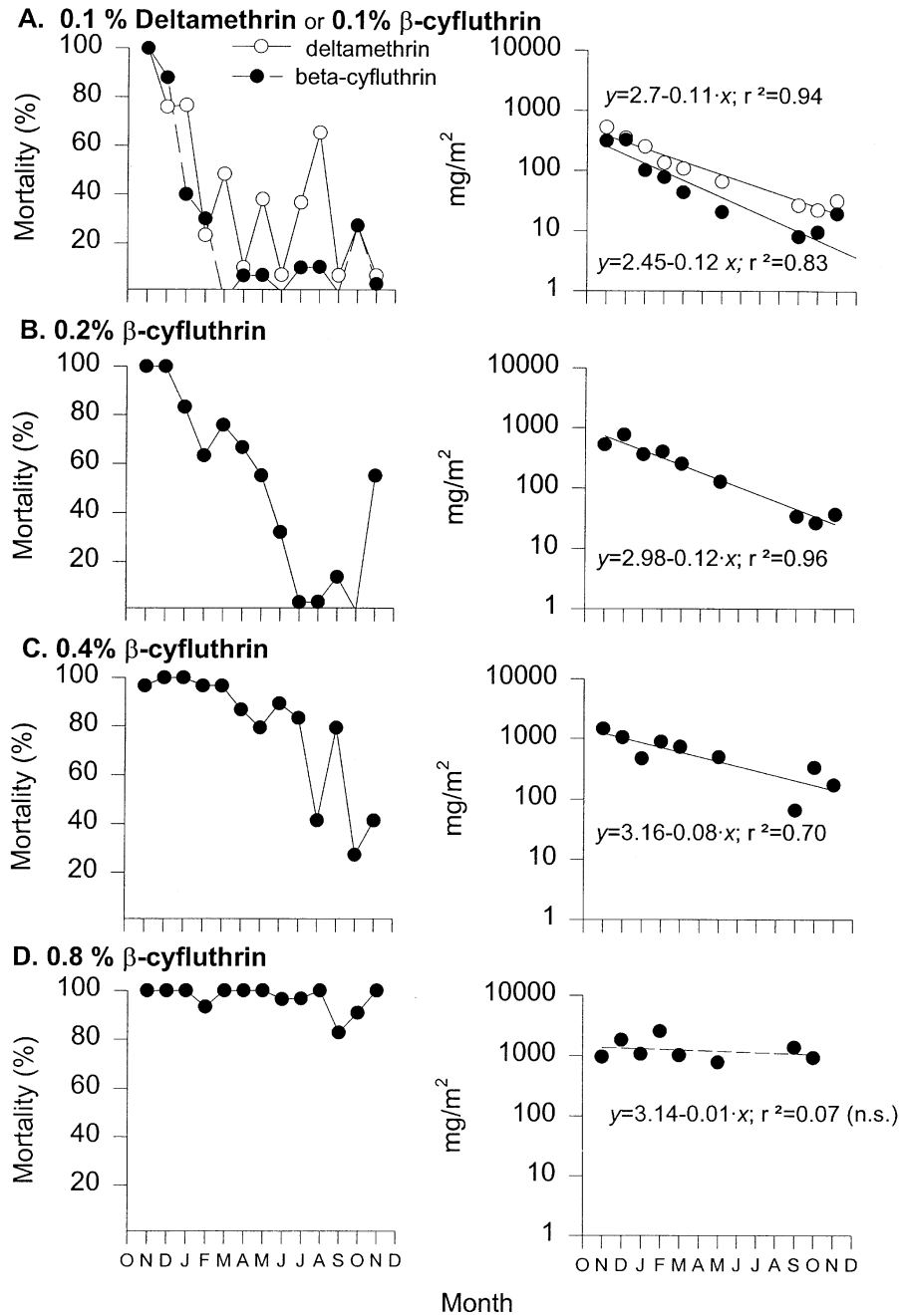
The results also suggest that alphacypermethrin must be applied at roughly twice the concentration of deltamethrin to obtain the same performance; in the direct comparisons between alphacypermethrin and deltamethrin the 0.2% alphacypermethrin s.c. was as effective as the 0.1% deltamethrin s.c. and in the second trial the 0.8% alphacypermethrin s.c. was as effective as 0.4% deltamethrin. Alphacypermethrin formulations are generally sold at approximately half the price of deltamethrin and thus alphacypermethrin s.c. may be as cost-effective as deltamethrin. Indeed, tsetse control operations in Zambia (S. Flint, personal communication) and Botswana (R. Allsopp, personal communication) are using this insecticide, applied as a 1% formulation.

The poorer performance of alphacypermethrin, when applied at equivalent concentrations, is presumably due, at least in part, to the inherent lower toxicity of alphacypermethrin compared to deltamethrin (S. Smith, unpublished data). However, the present results also indicate that the poorer performance of alphacypermethrin is also due to a faster rate of loss of insecticide; the regression coefficients for the change in the amount of insecticide on cloth were –0.09 for 0.4% deltamethrin compared to –0.14 for 0.4% alphacypermethrin.

Lambda-dacyhalothrin is not formulated commercially as an s.c. and the w.p. and c.s. formulations of this insecticide were found to be markedly inferior to deltamethrin s.c. Holloway (1989), testing various insecticides for their performance for ground spraying, also found that 0.1% lambda-dacyhalothrin w.p. was markedly inferior to either 0.2% alphacypermethrin s.c. or 0.1% deltamethrin s.c. The present results suggest that the poor performance of lambda-dacyhalothrin formulations is due in part to the rapid loss of insecticide from the cloth. Previous studies (Torr, 1985; Holloway, 1989) have also noted that wettable powder formulations are less resistant to rain weathering than suspension concentrates. The results for the poor performance of the lambda-dacyhalothrin w.p. are similar to those of Langley *et al.* (1992) who found that the w.p. formulation gave mortalities of ≈60% after 3 months and that the amount of active ingredient declined by 74% in 1 month and 94% by 3 months. They also found that an oil ('Cerechlor')-based formulation of lambda-dacyhalothrin was effective for ≈4 months during the wet season. This is not as effective as the 12 months of high mortality reported by Torr *et al.* (1992) for deltamethrin or *β*-cyfluthrin in the present paper. However, Langley *et al.* (1992) treated their targets with lambda-dacyhalothrin at just 12 mg/m<sup>2</sup> which is roughly 1% of the amounts of deltamethrin and *β*-cyfluthrin applied by Torr *et al.* (1992) and in the present study, respectively.

#### *Effects of concentration on persistence*

Torr *et al.* (1992) found that increasing the concentration of deltamethrin applied to a substrate increases the relative persistence of the insecticide. The present more extensive



**Fig. 4.** Percentage mortalities of female *G. pallidipes* exposed to cloth treated with various concentrations of  $\beta$ -cyfluthrin suspension concentrate (s.c.) or deltamethrin s.c and weathered for various periods (left-hand column), and the amount of insecticide on the materials (right-hand column). The trial commenced in October 1993. For plots of the amount of insecticide, lines were fitted by regression analysis following  $\text{Log}_{10}$  transformation of insecticide amounts ( $\text{mg/m}^2$ ) and with age in months as independent variable ( $x$ ).

data confirm these results and show that the same phenomenon occurs with deposits of alphacypermethrin and  $\beta$ -cyfluthrin. Torr *et al.* (1992) suggested two possible explanations for the concentration-dependent variation in the persistence of insecticide. First, they suggested that at higher concentrations there is a decrease in the surface

area/volume ratio of insecticide and thus the proportion of active ingredient directly exposed to weathering decreases with increasing quantities of insecticide. Secondly, they suggested that the efficacy of antioxidants that are normal constituents of insecticide formulations is related to the absolute amount present.

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