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CHEMICAL CONTROL OF THE HEARTWATER VECTORS

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ABSTRACT

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This paper reviews available literature on the efficacy of acaricides against *Amblyomma hebraeum* and other tick species, and presents information on tests done with registered chemicals in the laboratory.

Little published information is available on the efficacy of chemicals specifically against *A. hebraeum*. A host of formulations are registered for use as acaricides on cattle, sheep, and goats in South Africa and thus, by implication, against this species. Resistance has only been described to arsenic and toxaphene in Southern Africa; the other registered products are generally considered to be effective.

In contrast, many efficacy tests of various chemicals in different formulations against other *Amblyomma* spp. have been described. These publications have mainly emanated from the USA, where bite-wounds of these ticks serve as oviposition sites for screwworm flies. In this paper, *Amblyomma maculatum* and *Amblyomma variegatum* are included as potential heartwater vectors.

The acaricidal efficacy of a number of compounds, representative of different chemical classes, was tested in South Africa against an arsenic and organochlorine resistant strain of *A. hebraeum*. The engorged adult female immersion method was used. A disconcerting discovery was that several of these registered products failed to control this tick when used at their recommended concentrations.

It is concluded that many chemicals which fail against *A. hebraeum* on cattle do so because of insufficient persistence. Exposure of this tick to lower levels of existing chemicals, but for longer periods, ought to provide satisfactory control for many years.

INTRODUCTION

Chemicals remain the prime method by necessity, if not by choice, for controlling ticks on cattle in South Africa (Dorn, Hamel & Stendel, 1982). Many compounds are registered for use against ticks, including *Amblyomma hebraeum*, on cattle, goats, and sheep (Paterson, Schumacher & Stenson, 1986).

These compounds represent different chemical groups and, because resistance in *A. hebraeum* has only been described to arsenic (Matthewson & Baker, 1975) and toxaphene (Baker, Thompson & Miles, 1977), it is generally assumed that they are all effective. Results of an *in vitro* laboratory test, performed to gather information on the chemical susceptibility of one strain of *A. hebraeum* relative to other species, and on the relative efficacy of different compounds against *A. hebraeum* indicate that matters might not be so simple (J. Schröder & Alice A. Ford, Veterinary Test Unit, South African Bureau of Standards, East London, unpublished information, 1984).

Chemicals to control ticks can be applied to cattle topically by spraying and dipping (Matthewson & Baker, 1975), pour-on (Hamel, 1984), or by the application of impregnated devices such as ear tags, ear bands, horn bands, and neck bands (Ahrens, Gladney, McWhorter & Deer, 1977; Ahrens & Cocke, 1978; Gladney, 1976; Taylor, Kenny, Mallon, Elliott, McMurray & Blanchflower, 1984). Some compounds can be administered systemically as low-level feed additives, or in the form of oral sustained-release boluses, or may lend themselves to formulation as controlled-release injections (Drummond, Whetstone & Miller, 1981).

This paper reviews published information on the efficacy of chemical compounds against *A. hebraeum, Amblyomma maculatum* and *Amblyomma variegatum*. In addition, some of the results of the laboratory test are presented.

LITERATURE REVIEW

Efficacy against Amblyomma *spp.*

Favourable efficacy results were attained by Rechav, Whitehead & Terry (1978) in a larval immersion test with dioxathion, chlorfenvinphos, and oxionthophos. However, *A. hebraeum* was one of the least susceptible ticks in handspraying trials with chlorfenvinphos (Baker & Thompson, 1966), and flumethrin (Dorn *et al.*, 1982). It has been described as the most difficult to control of the tick species infesting livestock (Baker *et al.*, 1977).

Other chemical compounds to which *A. hebraeum* has been found to be susceptible include other organophosphates, such as dioxathion (Baker & Thompson, 1966), and propetamphos (Anonymous, 1981), and the diamidine amitraz (Haigh & Gichang, 1980). Table 1 provides a list of compounds registered for use in plunge-dipping tanks against ticks on cattle in 1982 (Paterson *et al.*, 1982), but no published information on their efficacy against *A. hebraeum* could be found.

In an FAO larval packet test, *A. variegatum* was tested in Zambia against dieldrin, dioxathion, dimethoate, and chlorfenvinphos (Luguru, Banda & Pegram, 1984). One of the 4 strains tested was found to be resistant to dieldrin. Flumethrin at a concentration of 2 mg/ℓ was 100 % effective against engorged adult female *A. variegatum* in an *in vitro* test (Stendel & Fuchs, 1982).

A. maculatum, the Gulf Coast tick, infests the outer ears of large mammals (Gladney, 1976). In recent years, the efficacy of ear tags and other impregnated devices for the control of this tick and the associated oviposition by *Cochliomyia hominovorax* has been described in several publications (Ahrens *et al.*, 1977; Ahrens & Cocke, 1978; Gladney, 1976). These devices were impregnated with different compounds, such as stirofos, chlorpyrifos, propoxur, fenvalerate, dichlorvos, and trimethylphenyl methylcarbamate. Ear tags containing 15 % stirofos or 8 % fenvalerate were found to provide effective protection against infestation with *A. maculatum* (Ahrens *et al.*, 1977; Ahrens & Cocke, 1978; Gladney, 1976) for up to 7 weeks in some instances (Gladney, 1976).

Systemic administration is advantageous where no plunge dip or spray facilities exist, and a sustained, slow-release system has the added attraction of a single application with a long duration of activity (Nolan, Schnitzerling & Bird, 1981). A sustained-release oral bolus which delivers famfur at the rate of 7 mg/kg live mass per day has been found to control *A. maculatum* and other ticks (Drummond *et al.*, 1981). The efficacy of repeated oral administration and subcutaneous injection of ivermectin has been tested against *A. maculatum, A. hebraeum* and other ticks (Drummond *et al.*, 1981; Schröder, Swan, Soll & Hotson, 1985). Daily oral doses of 50 μg/kg ivermectin were >90 % effective, and daily

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TABLE 1 Compounds registered for use in plunge-dipping tanks against ticks on cattle in South Africa (Paterson *et al.* 1986)

Chemical	Formu-lation*	Recommended concentration*	Trade name
Alphamethrin	e.c.	70	Paracide
Amitraz	w.p.	237,5	Taktik LS
		47,5	Taktik TR
		47,5	Triatix TR Cattle Dip
	w.p.	198	Triatix LS Cattle Dip
Bromophos ethyl + quinthiophos	e.c.	400 + 200	Bacnex
Camphechlor	e.c.	2 500	Coopertox Cattle Dip
			Bont-tox Dip and Spray
Camphechlor + Bromophos ethyl	e.c.	2 500 + 400	Nexagan-T Dip
Camphechlor + Dioxathion	e.c.	2 600 + 3 750	Altik Cattle Dip
Carbaryl	w.p.	1 715	Super-Sevin Cattle Dip
Chlorfenvinphos	e.c.	500	Bovitik Plus Cattle Dip
			Multidip Cattle Dip
			Repvet 30 Cattle Dip
			Steladone 30
			Supona 30 Cattle Dip
Chlorfenvinphos + camphechlor	e.c.	200 + 2 500	Disnis Livestock Dip
Chloromethiuron	f.c.	1 800	Dipofene Cattle Dip
			Ticolene
Cyhalothrin	e.c.	50	Librekto
			Piredip
Cymiazol	e.c.	300	Tifatol 30 EC Cattle
			Dip and Spray
Cymiazol + cypermethrin	e.c.	262 + 37,5	Ektoban
Cypermethrin	e.c.	150	Curatik Cattle Dip
			Barricade Cattle Dip
			Bartik Cattle Dip
Cypothrin	e.c.	120	Cyanatick
Deltamethrin	f.c.	60	Decatix
Diazinon	e.c.	300	Dazzel N.F.
Dioxathion	d.f.f.	500	Delnav D.F.F.
Dioxathion +	d.f.f.	250 + 230	Supamix DFF Dip
Chlorfenvinphos	e.c.	170 + 250	Supamix Cattle Dip
Fenvalerate	e.c.	200	Sumitik Cattle Dip
Flumethrin	e.c.	50	Bayticol
Propetamphos	e.c.	290	Biotic
			Bostan
Quinthiophos	e.c.	200	Bacdip

* w.p. = wettable powder, e.c. = emulsifiable concentrate, f.c. = flowable concentrate, d.f.f. = diluent free formulation, concentration in mg/ℓ (ppm)

subcutaneous injections of 10 μg/kg completely effective against induced infestations of *A. maculatum* (Drummond *et al.*, 1981). A single injection of 200 μg/kg ivermectin caused a significant reduction in the numbers of naturally acquired *A. hebraeum* on cattle for 14–28 d, and the same injection repeated at 14 d intervals caused cattle to have significantly fewer *A. hebraeum* from 14 d after the first to 14 d after the last injection (Schröder *et al.*, 1985).

Test methods

Potential test methods include initial *in vitro* screens, and *in vivo* methods. Examples of the former are the larval packet tests of Shaw (Shaw, 1966) and the FAO (Luguru *et al.*, 1984), the engorged adult female immersion method (Anon.; 1977; Baker, Jordaan & Robertson, 1979; Drummond, Ernst, Trevino, Gladney & Graham, 1973), and immersion methods using unfed immature or adult ticks, or engorged immatures (Baker *et al.*, 1977). In addition, acaricides can be applied topically to individual ticks by micro-applicator (Mansingh & Rawlins, 1979).

The merits and shortcomings of the *in vitro* methods are well known. In general, larval tests are used to test for resistance, whereas engorged adult female ticks are used for efficacy screening (Stendel, 1980). The validity of the larval bioassay system as an indicator of adult tick resistance has been questioned, because adults are less susceptible than larvae of the same strain (Solomon, Baker, Heyne & Van Kleef, 1979). Because of the differences between the various methods, results of different tests must be compared with extreme caution.

Determination of efficacy *in vivo* can be done by, for instance, hand-spraying (Baker & Thompson, 1966), or the so-called mini-dip method (Stendel, 1980). It seems logical that *in vivo* test methods, which use parasitic ticks, will yield more reliable results.

CHEMICAL SUSCEPTIBILITY OF SOUTH AFRICAN *AMBLYOMMA HEBRAEUM*

Materials and methods

While breeding ticks for acaricidal efficacy screening for pharmaceutical companies, the chemical sensitivity of the various tick strains maintained by the Veterinary Test Unit of the South African Bureau of Standards, East London, was determined. The strain of *A. hebraeum* used in these tests had originated from Coopers' Gulu research farm, and had been found to be resistant to arsenic and organochlorines (J. A. F. Baker, Kwanyanga Research Station, personal communication 1983). It had not been exposed to acaricides during its maintenance in the laboratory.

The susceptibility of engorged female ticks was tested by immersing them in different dilutions of the acaricides. The method followed was similar to that described by other authors (Anon., 1977); Baker *et al.*, 1979; Drummond *et al.*, 1973), with minor differences, mainly in the calculations. The factor of 20 000 (converting egg mass to number of eggs) in the formula of Drummond *et al.* (1973) has been omitted from our formula for calculating the reproductive estimate, and a survival factor (to eliminate tick mortality unrelated to treatment) has been added:

$$\%\ \text{control} = \frac{Rc - Ra}{Rc} \times 100, \qquad R = \frac{A.N.H}{B.S.4},$$

where R = reproductive estimate, A = mass of eggs (mg), B = mass of ticks (mg), N = total number of ticks exposed, S = number of ticks not discoloured by d 7

TABLE 2 Efficacy of various chemicals against engorged female *A. hebraeum in vitro*

Compound	Concentration (mg/ℓ)			LC_{50}	LC_{95}
	Recommended	Test	Efficacy (%)		
Cypermethrin	150	100 200 400 800	12,4 28,2 53,1 76,7	365 ±28	2 213 ±483
Fenvalerate	200	100 200 400 800	35,8 52,5 43,5 88,7	N.C.*	N.C.
Chlorfenvinphos	500	100 200 400 800	100 100 100 100	N.C.	N.C.
Quithiophos	200	200 400 800 1 600	88,0 100 100 100	N.C.	N.C.
Bromophos ethyl	4 000	1 000 2 000 4 000 8 000	1,1 14,4 74,4 86,5	N.C.	N.C.
Carbaryl	1 500	500 1 000 2 000 4 000	39,2 49,7 71,5 92,0	842 ±85	7 124 ±1 629
Campheclor	2 500	2 000 4 000 8 000 16 000	0 3,5 23,4 67,2	12 276 ±707	33 389 ±4 738
Amitraz	250	100 200 400 800	71,7 78,2 97,5 100	N.C.	N.C.

* N.C.: Not calculated, because of an inadequate scatter of data points

(natural mortality correction), H = egg hatchability (0–4 scale), a = treated, c = untreated control.

Two synthetic pyrethriods (cypermethrin, and fenvalerate), 3 organophosphates (bromophos ethyl, chlorfenvinphos, and quinthiophos), a carbamate (carbaryl), a chlorinated hydrocarbon (camphechlor), and a diamidine (amitraz) were used.

Results

Table 2 summarizes the concentrations and efficacies of acaricides against engorged adult female *A. hebraeum*.

Cypermethrin, fenvalerate, and amitraz were effective at substantially higher concentrations than the recommended levels. The organophosphates and carbaryl showed good to doubtful efficacy at their recommended concentrations, and the strain was relatively insensitive to camphechlor.

Discussion

This test method has shortcomings. It is unsuitable for non-topical formulations, residual activity cannot be determined, the test tick is no longer parasitic, and the test is lengthy. However, it does provide useful comparative efficacy data for topical formulations.

An arsenical compound was not used in our test, so we cannot comment on the susceptibility of the strain of *A. hebraeum* we used. This strain did, however, live up to its reputation for organochlorine resistance, as can be seen from its low sensitivity to camphechlor. It was disconcerting that such high levels of cypermethrin, fenvalerate, and amitraz were needed to achieve efficacy. To the best of our knowledge, this tick had not previously been exposed to these chemicals.

CONCLUSION

Although it is tempting to use a moderate tick infestation to maintain a premunity against heartwater in cattle, such a regimen is not advisable. Firstly, because the transmission rate necessary to maintain the enzootic stability of heartwater is unknown. Secondly, because the infection rate of the tick population is highly variable. And thirdly, because it is undesirable to have on the animals the large number of *A. hebraeum* that would be required if the infection rate is low (Bezuidenhout, 1985).

It therefore seems inevitable that acaricides will still be applied to cattle for some time. The traditional means of plunge-dipping, spray races, and hand-spraying are in the process of being replaced by labour-saving and less capital-intensive methods of application. Chemicals which have been in use for years can now be used in impregnated topical devices, or sustained-release systemic boluses. New chemicals may lend themselves to formulation as pour-ons, or as controlled-release injections, but they will have to satisfy the need for high potency, and low tissue residues at slaughter.

It has been said that sub-lethal doses of acaricides, which either inhibit oviposition or render tick eggs nonviable, can provide a valuable adjunct to integrated tick management, especially against small tick populations, where even so-called "lethal" doses are not always effective (Mansigh & Rawlins, 1979). Although this statement was made with reference to *Boophilus microplus*, it is supported by observations made on *A. hebraeum*. Residual concentrations of 10 % (i.e. 3 mg/kg) of the applied concentration of flumethrin were found on cattle 7 d after spraying (Dorn *et al.*, 1982). Laboratory tests had shown that concentrations of flumethrin of 1,0–4,0 mg/ℓ inhibited oviposition by *A. hebraeum* (Stendel & Fuchs, 1982). In addition, flumethrin retards engorgement of female *A. hebraeum* on cattle (Dorn *et al.*, 1982).

This latter observation corresponds to one made by Drummond *et al.* (1981) after administering ivermectin to cattle. Artificially induced infestations of 3-host ticks failed or took longer to engorge. Ivermectin was also found to retard engorgement of female *Rhipicephalus appendiculatus*, another 3-host tick of cattle (Schröder, Louw & Meyer, 1981).

Apparently, therefore, existing acaricides can control *A. hebraeum*, provided that they remain in contact with the tick for long enough, either through persistence after a single application, or through sustained release from an impregnated device or depot-injection. If a regimen does not keep the cattle free from visible ticks, stockmen might object to the prolonged presence of either unengorged or semi-engorged ticks on their cattle.

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