The Trypanosomiases

Edited by

Ian Maudlin
Professor and Director, Centre for Tropical Veterinary Medicine,
University of Edinburgh, Edinburgh, UK

Peter H. Holmes
Professor and Vice-Principal, University of Glasgow, Glasgow, UK

Michael A. Miles
Professor, Department of Infectious and Tropical Diseases,
London School of Hygiene and Tropical Medicine, London, UK

CABI Publishing

29 The Application of Bait Technology to Control Tsetse

Peter Van den Bossche and Reginald De Deken

Baits have been used since the early days of tsetse control. In Zululand, for example, traps were used to control *Glossina pallidipes* (Harris, 1932), and DDT-treated oxen were effective tools to combat tsetse in Tanzania (Whiteside, 1949). Despite these initial successes, it took several decades before baits were recognized as an integral part of the arsenal of tsetse control methods. This was because the original baits were not sufficiently practical and cost-effective, and results were often not reproducible. The situation changed drastically after systematic research into tsetse's behaviour added a scientific backing to the principles governing tsetse's responses towards baits (Gouteux *et al.*, 1981; Vale, 1993). Since then, baits have become increasingly effective, simple, more user-friendly and less damaging for the environment. Furthermore, the development of persistent pyrethroid insecticides that are highly effective against tsetse offered the possibility of using baits that were toxic for long periods, so avoiding the need for frequent re-treatments. As a result of the better understanding of bait technology, baits have successfully controlled a wide range of tsetse species. However, sometimes the basic principles of bait technology are ignored, with ensuing disappointing results. This chapter describes the factors determining the effectiveness of bait control under various epidemiological circumstances.

Effectiveness of Baits to Control Tsetse

Several factors contribute to the effectiveness. Some, such as bait size and odour, are features of the baits themselves and have been considered in Chapter 28. Other factors are external, including matters such as the distribution of the tsetse population in relation to the position of the baits, the tsetse's preference for the bait as against wildlife, and the invasion pressure of tsetse. A bait intervention will only be effective when both the inherent and external factors have been taken into account. This may be easy with inherent factors. External considerations, on the other hand, are not always well understood and applied.

The interaction between tsetse and baits can be optimized by adjusting the distribution and density of baits according to the dynamics of the local tsetse population (Chapter 7). This means that stationary baits are options to consider in most areas as long as their numbers, distribution and upkeep can be managed. The situation is different when mobile baits are used, because the distribution and density of cattle is hard to dictate. Grazing patterns of cattle vary between livestock management practices, which may in turn change according to the season (D'Amico *et al.*, 1995; Scoones, 1995; de la Rocque *et al.*, 2001). Usually, cattle are kraaled and herded away from cropped areas during the rainy season. After crops have been gathered, cattle are allowed to roam free and feed unsupervised, mainly on crop residues. As the dry season progresses the cattle are forced to move further afield and to find diverse foods.

General Patterns in Effectiveness of Baits

It is possible to recognize some general patterns in the effectiveness of the different types of baits under the various epidemiological situations. For many years, the rapidly expanding human populations have, together with their livestock, encroached on areas where game is the main food source of tsetse. This encroachment has resulted in significant changes in the interaction between tsetse and livestock and has had important repercussions on the local epidemiology of animal trypanosomiasis, as detailed below.

The local epidemiology of trypanosomiasis usually follows a sequence commencing with the introduction of people and livestock into a tsetse-infested area and the subsequent progressive clearing of natural vegetation for cultivation. The epidemiological changes are a direct consequence of the gradual reduction in the number of wild hosts and the increase in the density of livestock and humans, so that tsetse usually become increasingly dependent on livestock as food. Progressive clearing of natural vegetation makes an area less suitable for the fly. Finally, the savannah species of tsetse will be confined to marginal, often protected, areas where wildlife and suitable habitat are still abundant, e.g. national parks, game management areas or forest reserves. Game animals will again constitute an important host. The interaction between tsetse and livestock will be restricted to the interfaces where the distributions of livestock and tsetse overlap, such as the edges of protected wildlife zones or watering points. Riverine species of tsetse, on the other hand, seem to adapt better to changes in the environment and often survive in the remaining sparse vegetation along rivers or lakes, in residual forests (*fôrets sacrés*) and in plantations, feeding on domestic animals and humans (Gouteux and Laveissière, 1982; Mwangelwa *et al.*, 1990).

Although these modifications in the tsetse's environment and the resulting changes in the interaction between tsetse and livestock are gradual processes, it is possible to distinguish within it four stages that affect the choice of a bait method (Table 29.1 and Fig. 29.1).

Game areas (Fig. 29.1a)

When pressure for land is high, tsetse may be controlled in game areas to make them suitable for livestock production, or a barrier may be erected to prevent tsetse from invading into adjacent settlements. Traps or targets are the only possible bait methods to employ, since cattle are absent, or present at very low density. The effectiveness of stationary baits in such circumstances has been proved on various occasions (Green, 1994). In southern Africa, vast areas of uninhabited flat and hilly terrain suitable for livestock production have, for example, been cleared of savannah species of tsetse using various modifications of the target technology (Lovemore, 1999).

Areas recently reclaimed with low densities of cattle (Fig. 29.1b)

Where cattle are present at low density and trypanocidal drugs offer insufficient protection, baits can be used to control tsetse and reduce the incidence of trypanosomiasis, without necessarily eliminating the flies. The effectiveness of insecticide-treated cattle may well be limited in these situations. This is because treated cattle will have to compete with many other baits, such as warthogs and bushpigs, the most important wild hosts of the *morsitans* group of tsetse in eastern and southern Africa (Weitz, 1963; Robertson, 1983). Although tsetse do feed on domestic animals, an increase in the number of cattle does not necessarily decrease the proportion of feeds taken from wild hosts. For example, a survey conducted

Table 29.1. Expected effects of the introduction of cattle and vegetation clearing in an area infested with savannah species of tsetse on the epidemiology of trypanosomiasis and effectiveness of bait method.

Epidemiological situation	Figure	Population density			Host preference		Effectiveness of bait method	
		Tsetse	Cattle	Game	Game	Cattle	Stationary	Mobile
Game areas	29.1a	+++	(+)	+++	+++		+++	–
Areas recently reclaimed with low densities of cattle	29.1b	+++	+	++	++	+	+++	–
Cultivated areas with high densities of cattle	29.1c	++	++(+)	+	+	++	+++	+++
Cattle/tsetse interface	29.1d	+	+++	+	+++	+	+++	–

(+) = importance between – and +
++(+) = importance between ++ and +++

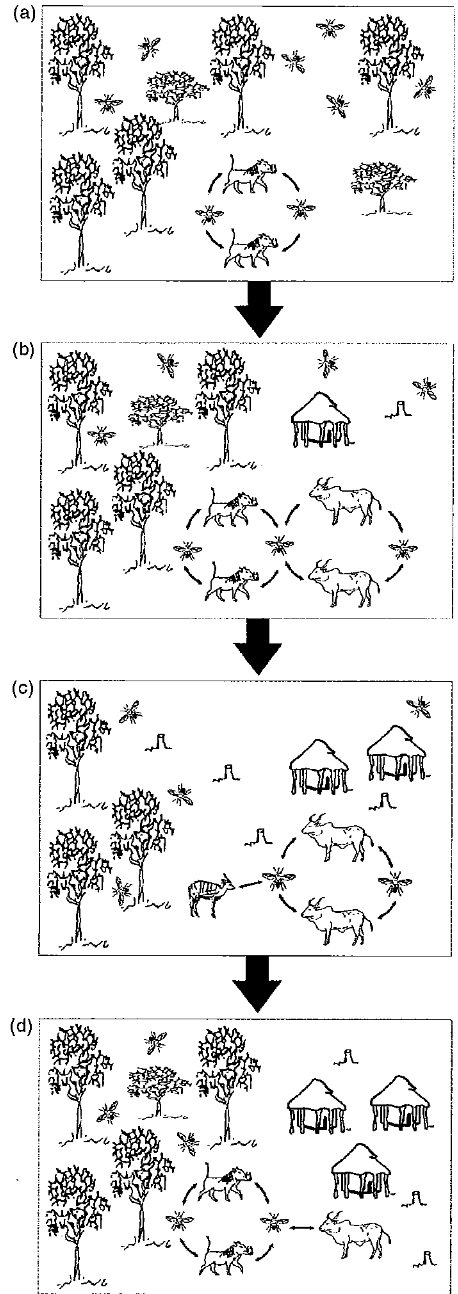

Fig. 29.1. The consequence of gradual encroachment of people and livestock into an area infested with savannah species of tsetse on the epidemiology of bovine trypanosomiasis. Reprinted from Van den Bossche, P. *Some General Aspects of the Distribution and Epidemiology of Bovine Trypanosomiasis in Southern Africa*; copyright (2001), with permission of Elsevier Science.

in Mkwaja Ranch in Tanzania, where cattle formed 75% of the animal biomass, revealed that they only provided 5–6% of the total bloodmeals, while *c.* 75% were from warthogs and bushpigs (Gates and Williamson, 1984). Reliance on insecticide-treated cattle in those circumstances is thus unlikely to be satisfactory and stationary baits are probably the most effective control method (Table 29.1).

Cultivated areas with high densities of cattle (Fig. 29.1c)

The effectiveness of insecticide-treated cattle rises with increasing density and wider distribution of cattle and with the concomitant decrease in the density of wild hosts. Tsetse are then obliged to take a higher proportion of bloodmeals on cattle. For example, because of the scarcity of game animals in the densely cultivated areas of the eastern plateau of Zambia, up to 75% of bloodmeals were taken from cattle (Van den Bossche and Staak, 1997). Similar observations have been made elsewhere (Robertson, 1983; de la Rocque *et al.*, 2001). In such circumstances, insecticide-treated cattle are usually an effective alternative to stationary baits against savannah species of tsetse, or could be used in combination with traps or targets to mop up residual tsetse foci. In eastern Zimbabwe, deltamethrin treatments of cattle dealt effectively with bovine trypanosomiasis in a highly cultivated area of *c.* 2500 km^2 along the border with Mozambique (Thomson and Wilson, 1992). Similarly, in the pastoral zone of Yalé in Burkina Faso, the application of a pyrethroid pour-on to cattle caused a spectacular decline in the incidence of trypanosomiasis (Bauer *et al.*, 1999).

Cattle/tsetse interface (Fig. 29.1d)

After the extensive clearing of vegetation has made an area unsuitable for permanent occupation by a self-sustaining tsetse population, tsetse control operations aim to prevent occasional or seasonal invasions from the adjacent, tsetse-infested areas. This may require an invasion barrier at the livestock/tsetse interface. Although cultivation usually results in a steep decline and often eradication of tsetse, this is usually not the case for the riverine species. Such species can persist in patches of often sparse vegetation along rivers, feeding on various hosts, including cattle. Interaction between cattle and tsetse can be high along the interfaces of this fragmented habitat, especially during the dry season when cattle are watered along the rivers. In this case, insecticide-treated cattle may be an effective tool to control flies. However, the interaction may be too short and too irregular to eradicate the tsetse population. A combination of mobile and stationary baits, or stationary baits on their own, may be more appropriate for this purpose.

Effectiveness of Baits to Prevent Invasion by Tsetse

Reinvasion by tsetse is a serious threat to the success of any tsetse control operation. The tsetse's potential to reinvade areas is demonstrated by considering the speed with which the tsetse invasion front advanced after the southern African rinderpest epizootic at the end of the 19th century (Jack, 1914). In areas where the rate of tsetse invasion is high, the continuous replenishment of the tsetse population may make the population's growth rate higher than the mortality rate, even in the presence of baits. This is likely to occur when mobile savannah species of tsetse are controlled in a small area surrounded by tsetse-infested land (Hargrove, 2000). Under such circumstances, control can be achieved after the operational area has been extended to reach either a natural barrier to invasion, or an area of manageable invasion pressure such as the edge of the fly belt. Alternatively, artificial barriers to invasion can be put in place. Artificial barriers may also be required to protect areas once tsetse have been cleared, or to minimize the interaction between tsetse and livestock at the interface of a tsetse-infested protected zone and a cultivated area unsuitable for tsetse (Fig. 29.1d). The current trend towards tsetse control in relatively small areas and the need to protect such areas, once tsetse have been cleared, means that artificial barriers to tsetse invasion are becoming increasingly important.

An artificial barrier must limit penetration by tsetse to such an extent that a self-sustaining population cannot be established behind the barrier, or cause a significant level of challenge at the edge of a cultivated area. An effective barrier to the invasion of *Glossina mortisans morsitans* and *G. pallidipes* can be obtained by deploying targets in a band 6–8 km wide along the invasion front with target density required for control (Hargrove, 1993). Such target barriers have been used extensively in Zimbabwe to prevent tsetse from reinvading from the wildlife areas in the Zambezi Valley and neighbouring Mozambique (Lovemore, 1999). In Malawi, target barriers have been used effectively to reduce the challenge of cattle along the edges of tsetse-infested game parks (Van den Bossche *et al.*, 2000). In the north of Cameroon, targets were effective barriers against the massive invasion pressure of *G. m. submorsitans* (Cuisance and Boutrais, 1995). Traps can also act as effective barriers to invasion of riverine species of tsetse. For example, the deployment of traps not treated with insecticide at 100 m intervals along 10 km of a riverine system in Burkina Faso protected previously cleared areas (Politzar and Cuisance, 1983).

Hence for savannah species of tsetse, targets deployed in any 8 km wide section of a control operation can, if necessary, act as a barrier without the need to adjust the deployment pattern. In areas that are cleared progressively, target barriers can be moved forward gradually and act as a rolling carpet of baits until the planned area has been cleared completely or a natural barrier to invasion has been reached. The question remains as to whether insecticide-treated cattle constitute an effective barrier to such reinvasion. This depends largely on the probability that invading flies contact a treated herd, which in turn depends on the distribution of treated herds. In a commercial farming system the distribution of herds can, to a certain extent, be altered according to the requirements. Under communal conditions, however, cattle distribution undergoes substantial seasonal changes. Because of this seasonality it is almost impossible to ensure an even distribution of insecticide-treated cattle throughout the year. This was demonstrated clearly in eastern Zimbabwe (Warnes *et al.*, 1999) and the Ghibe Valley of Ethiopia (Rowlands *et al.*, 2000), where insecticide-treated communal cattle were unable to prevent tsetse from moving into tsetse-free areas. Furthermore, flies that visit the treated cattle may die afterwards but not before many of them feed, and so treated cattle near an invasion front will be challenged continuously (Baylis *et al.*, 1994; Vale *et al.*, 1999). Stationary baits, on the other hand, can be deployed in accordance with the distribution of suitable tsetse habitat, and thus constitute effective barriers.

Sustainability of a Bait Intervention

Throughout the long history of tsetse control, large areas have been cleared using a variety of tsetse control methods. Unfortunately, many of the areas that once were fly-free have been reinvaded. For the most part, the failure of governments to sustain the clearance has been due to the inability to meet the recurrent costs of invasion barriers or suppression operations. In the 1990s, guided by the redefinition of a government's responsibility for controlling animal diseases and supported by the availability of low-technology bait methods, a range of measures has been proposed that were expected to contribute to the sustainability of tsetse control. Broadly speaking, this came down to shifting most of the responsibility for tsetse control on to the local communities. However, few of the bait campaigns to control animal trypanosomiasis have been successful when relying heavily on the support of local communities

There are numerous definitions of sustainability. In the context of tsetse control by stakeholders, a campaign could be considered sustainable when it produces benefits valued sufficiently by the stakeholders to ensure the allocation of adequate internal and/or external resources to continue activities with long-term benefits. The main stakeholders are the cattle owners in the area under control, including those who visit the area temporarily such as transhumant pastoralists.

The evaluation of benefits and the willingness to contribute to community efforts are largely dependent on the way the benefits are perceived. Willingness to contribute is usually high in epidemic areas, where trypanosomiasis-related mortality in livestock is high, or in an endemic situation where highly valued livestock (oxen and cows) are at risk. In areas where tsetse cannot be eradicated, the benefits accruing from fly suppression are perceived mostly in the beginning of the campaign, when the effects of a declining challenge on animal health are often spectacular (Bauer *et al.*, 1992; Knols *et al.*, 1993). Once the tsetse population has been reduced substantially and challenge is low, the willingness to allocate sufficient resources to sustain the campaign usually declines (Cuisance *et al.*, 1991; Barrett and Okali, 1998). Hence, bait campaigns supported by beneficiaries are often considered to be unsustainable. It is, however, plausible that the decision made by the stakeholders to continue or halt a control campaign is based on a careful consideration of the perceived benefits of the campaign and the amount of often scarce resources required. A decision to abandon a control operation may be taken when the tsetse population has been suppressed sufficiently to reduce challenge to an acceptable level. On the other hand, initiation or resurrection of control is possible when challenge increases and the benefits perceived from alternative and often cheaper control methods (e.g. trypanocidal drugs) are insufficient. Hence, the sustainability of bait campaigns may be related to the capability of the stakeholders to implement an operation when required, rather than the capability to maintain an ongoing operation indefinitely. If this is the case, the sustainability of such 'strategic' tsetse control interventions will depend on the availability of the necessary inputs and the organizational capacity of the stakeholders. The latter may require involvement of the public or private sector. The availability of inputs is affected by the socio-economic environment in which bait operations are conducted. Availability of foreign exchange may, for example, be an important determinant in the acquisition of certain inputs, such as insecticides and some odour attractants.

To ensure optimal effectiveness of a reinvasion barrier, the maintenance of the baits requires careful planning, coordination and sometimes coercion. Often the local communities cannot meet these requirements. Besides, people near the invasion front must play the most crucial role in stopping invasion, and these are the people who may see least benefit from the effort. Hence, it is unlikely that stakeholders living on or near the front would be willing to participate in ventures of this kind for long, particularly if they have to pay for the inputs at unsubsidized prices. The maintenance of a reinvasion barrier is thus best sustained technically and financially by the public sector, possibly assisted by the private sector. In western Zambia, for example, the government issues private tenders for the maintenance of a target barrier along the Zambezi River.

Continued control of tsetse may have side-effects that reduce the perceived benefits accruing from the campaign and jeopardize sustainability. The side-effects seem most serious with insecticide-treated cattle. The intervals at which cattle are treated with insecticide for tsetse control are usually too long for complete control of ticks, but the prolonged application of pyrethroids to a large number of cattle may affect tick numbers, especially with the one-host types such as *Boophilus* spp. This will reduce the transmission of *Babesia* spp., the parasites responsible for redwater, and so prevent the development and maintenance of enzootic stability for the disease. Reduced immunity against *Babesia bigemina* has been observed in large parts of eastern Zimbabwe where insecticide-treated cattle have been used for tsetse control (Van den Bossche and Mudenge, 1999). A further problem is that ticks may become resistant to the pyrethroids used for tsetse control, so removing these pyrethroids from the list of chemicals that can be used on those occasions when tick control is needed. The development of behavioural resistance in tsetse after prolonged use of insecticide-treated cattle may also form a potential threat to the sustainability of this method. Finally there is the risk that the insecticide will affect dung fauna, and hence the effectiveness and rate at which manure is recycled.

In general, the side effects on ticks, tsetse and dung fauna are insufficient to threaten seriously the sustainability of insecticide-treated cattle. Nevertheless, research must be undertaken to recognize and minimize the extent of these possible problems.

References

Barrett, K. and Okali, C. (1998) Partnerships for tsetse control – community participation and other options. *World Animal Review* 90, 39–46.

Bauer, B., Kabore, I., Liebisch, A., Meyer, F. and Petrich-Bauer, J. (1992) Simultaneous control of ticks and tsetse flies in Satiri, Burkina Faso, by the use of flumethrin 'pour-on' for cattle. *Tropical Animal Health and Production* 43, 41–46.

Bauer, B., Amsler-Delafosse, S., Kaboré, I. and Kamuanga, M. (1999) Improvement of cattle productivity through rapid alleviation of African animal trypanosomiasis by integrated disease management practices in the agropastoral zone of Yalé, Burkina Faso. *Tropical Animal Health and Production* 31, 89–102.

Baylis, M., Mbwabi, A.L. and Stevenson, P. (1994) The feeding success of tsetse flies, *Glossina pallidipes* (Diptera: Glossinidae), on oxen treated with pyrethroid 'pour-ons' at Galana Ranch, Kenya. *Bulletin of Entomological Research* 84, 447–452.

Cuisance, D. and Boutrais, J. (1995) *Evaluation de la situation et de la stratégie de lutte contre les glossines et les trypanosomoses dans l'Adamaoua (Cameroun).* Centre de Coopération Internationale en Recherche Agronomique pour le Développement – Elevage et Médecine Vétérinaire, Montpellier, France, 63 pp.

Cuisance, D., Cailton, P., Kota-Guinza, A., Ndokoué, F., Pounekrozou, E. and Demba, D. (1991) Lutte contre *Glossina fuscipes fuscipes* par piègeage chez les éleveurs Mbororo de République Centreafricaine. *Revue d'Élevage et de Médecine Vétérinaire des Pays Tropicaux* 44, 81–89.

D'Amico, F., Poussinga, J.M., Le Masson, C., Le Masson, A. and Cuisance, D. (1995) Pratiques pastorales Mbororo et trypanosomoses bovines dans une zone de savanes humides de Centrafrique. *Revue d'Élevage et de Médecine Vétérinaire des Pays Tropicaux* 48, 203–212.

Gates, D.B. and Williamson, D.L. (1984) Tsetse fly feeding preference as determined by vehicular trapping in Tanzania. *Annals of Tropical Medicine and Parasitology* 78, 301–306.

Gouteux, J.P. and Laveissière, D.C. (1982) Ecologie des glossines en secteur pré-forestier de Côte d'Ivoire. 4. Dynamique de l'écodistribution en terroir villagois. *Cahier ORSTOM, Série Entomologie Médicale et Parasitologie* 20, 199–229.

Gouteux, J.P., Challier, A. and Laveissière, C. (1981) Modifications et essais des pièges à glossines. *Cahier ORSTOM Série Entomologie Médicale et Parasitologie* 19, 87–99.

Green, C.H. (1994) Bait methods for tsetse fly control. *Advances in Parasitology* 34, 229–291.

Hargrove, J.W. (1993) Target barriers for tsetse flies (*Glossina* spp.) (Diptera: Glossinidae): quick estimates of optimal target densities and barrier widths. *Bulletin of Entomological Research* 83,197–200.

Hargrove, J.W. (2000) A theoretical study of the invasion of cleared areas by tsetse flies (Diptera: Glossinidae). *Bulletin of Entomological Research* 90, 201–209.

Harris, R.H.T.P. (1932) Some facts and figures regarding the attempted control of *Glossina pallidipes* in Zululand. *South African Journal of Science* 29, 495–507.

Jack, R.W. (1914) Tsetse fly and big game in Southern Rhodesia. *Bulletin of Entomological Research* 5, 97–110.

Knols, B.G.J., Willemse, L., Flint, S. and Mate, A. (1993) A trial to control the tsetse fly, *Glossina morsitans centralis*, with low densities of odour-baited targets in west Zambia. *Medical and Veterinary Entomology* 7, 161–169.

Lovemore, D.F. (1999) *Final Report for the Zimbabwe Component of the First and Second Phases of the Regional Tsetse and Trypanosomiasis Control Programme Malawi, Mozambique, Zambia and Zimbabwe 1986–1998.* Regional Tsetse and Trypanosomiasis Control Programme, Harare, 163 pp.

Mwangelwa, M.I., Dransfield, R.D., Otieno, L.H. and Mbata, K.J. (1990) Distribution and diel activity patterns of *Glossina fuscipes fuscipes* Newstead on Rusinga island and mainland in Mbita, Kenya. *Insect Science and its Application* 11, 315–321.

Politzar, H. and Cuisance, D. (1983) A trap-barrier to block re-invasion of a river system by riverine tsetse species. *Revue d'Élevage et de Médecine Vétérinaire des Pays Tropicaux* 36, 364–370.

Robertson, A.G. (1983) The feeding habits of tsetse flies in Zimbabwe (formerly Rhodesia) and their relevance to some tsetse control measures. *Smithersia* 1, 1–72.

de la Rocque, S. de, Michel, J.F., Cuisance, D., De Wispelaere, G., Augusseau, X., Arnaud, M. and Guilobez, S. (2001) *Du satellite au microsatellite. Le risque trypanosomien. Une approche globale pour une décision locale.* CIRAD, Montpellier, France, 151 pp.

Rowlands, G.J., Leak, S.G.A., Woudyalew Mulatu, Nagda, S., Wilson, A. and d'Ieteren, G. (2000) Use of deltamethrin 'pour-on' insecticide for the control of cattle trypanosomiasis in the presence of high tsetse invasion. *Medical and Veterinary Entomology* 15, 87–96.

Scoones, I. (1995) Exploiting heterogeneity: habitat use by cattle in dryland Zimbabwe. *Journal of Arid Environments* 29, 221–237.

Thomson, J.W. and Wilson, A. (1992) The control of tsetse flies and trypanosomiasis by the application of deltamethrin to cattle. *Bulletin of Animal Production in Africa* 40, 5–8.

Vale, G.A. (1993) Development of baits for tsetse flies (Diptera: Glossinidae) in Zimbabwe. *Journal of Medical Entomology* 30, 831–842.

Vale, G.A., Mutika, G. and Lovemore, D.F. (1999) Insecticide-treated cattle for controlling tsetse flies (Diptera: Glossinidae): some questions answered, many posed. *Bulletin of Entomological Research* 89, 569–578.

Van den Bossche, P. and Mudenge, D. (1999) The effect of short-interval deltamethrin applications, to control tsetse, on the prevalence of babesiosis. *Tropical Animal Health and Production* 31, 215–222.

Van den Bossche, P. and Staak, C. (1997) The importance of cattle as a food source for *Glossina morsitans morsitans* Westwood (Diptera: Glossinidae) in Katete District, Eastern Province, Zambia. *Acta Tropica* 65,105–109.

Van den Bossche, P., Shumba, W. and Makhambera, P. (2000) The distribution and epidemiology of bovine trypanosomiasis in Malawi. *Veterinary Parasitology* 88, 163–176.

Warnes, M.L., Van den Bossche, P., Chihiya, J., Mudenge, D., Robinson, T.P., Shereni, W. and Chadenga, V. (1999) Evaluation of insecticide-treated cattle as a barrier to re-invasion of tsetse flies to cleared areas in north-eastern Zimbabwe. *Medical and Veterinary Entomology* 13, 177–184.

Weitz, B. (1963) The feeding habits of *Glossina*. *Bulletin of the World Health Organization* 28, 711–729.

Whiteside, E.F. (1949) An experiment in the control of tsetse with DDT-treated oxen. *Bulletin of Entomological Research* 40, 123–134.