A REVIEW OF THE EVOLUTION OF TRAPPIING STRATEGIES FOR THE CONTROL OF TRYPANOSOMIASIS AND TSETSE FLIES (G*LOSSINA SPP*) IN AFRICA (1908 -2004)

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ABSTRACT
Trypanosomiasis is a protozoan disease transmitted by blood-sucking tsetse flies (Glossina spp.) in man and some land vertebrates in sub-Saharan Africa. It is among the major constraints to socio-economic development in the region owing to their debilitating and fatal effects on man and his domestic animals. This paper reviews the changes in the development of control strategies against the disease over the century, and briefly appraises the prospects of the success of a newly launched continental eradication campaign programme. Several strategies have been employed to contain the disease since the turn of the 20th century. These included chemo-therapeutic and chemo- prophylactic control of infections and attacks on vector populations, such as partial or complete clearance of vegetation (habitat) and destruction of wild reservoir hosts (food source) and the use of insecticidal sprays. The results varied from total failure in most places to partial success in a few. Failure in control could be attributed to inadequate knowledge on the biology, ecology and behaviour of the vector-parasite-host relationship. The failure of insecticides, especially DDT, to achieve permanent control prompted scientists to intensify research and make concerted effort to find more sustainable and environmentally friendly alternative control strategies. Today, efficient odour-baited attracting mechanical killing devices have been developed which, through pilot control projects, have proved to be effective in causing drastic reduction of vector populations and subsequent disease prevalence. The results from these trials have convinced the African Union (AU) to formulate a policy for the eradication of tsetse flies and trypanosomiasis, The Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC), for adoption by all African countries that are infested with tsetse flies. The programme was launched in 2005, in many parts of Africa including Ghana.

INTRODUCTION
African trypanosomiasis, commonly called sleeping sickness in humans and 'nagana' in animals, is among many factors responsible for limiting the space and extent of rural development in much of tropical Africa. The distribution and abundance of tsetse flies was initially documented by Glasgow (1963), the first distribution maps produced by Ford (1970), revised by Ford and Katondo (1977), and latest by Kotando (1984). Mulligan (1970) gave a good historical account of the realization and effects

of African trypanosomiasis. Jordan (1995) pointed out that restriction on the keeping of domestic livestock, particularly cattle, has not only affected the supplies of meat and milk but has also hampered the development of mixed arable and livestock farming. According to him there are 23 species of *Glossina,* the tsetse flies which feed only on vertebrate blood. Baldry (1983) recons that they are distributed over approximately 10 million km^2 of Africa between latitudes 15^o N and 22^o S, occupying a wide variety of vegetation types and transmit six (6) different trypanosome species of immense socio-economic importance: *Trypanosoma brucei gambiense* to man in western Africa; *T. b. rhodensiese* to man in eastern Africa; and *T. congolense*, *T. vivax, T. b..brucei* and *T. simaie* to livestock in eastern, central and southern Africa.

Long before the economic importance of trypanosomiasis was realized a stable ecological system had been established among the tsetse flies, the trypanosomes and the African game animals. Like most vector-borne parasitic diseases, trypanosomiasis is a relatively recent association with man and his domestic livestock and their pathological response to the infection is evidence that the parasites are still maladapted to these hosts (Duggan, 1970). The evolution and ecology of tsetse flies and trypanosomiasis in prehistoric African environment has been reviewed by Lambrecht (1964).

The colonialists initiated the control of trypanosomiasis by 1908 when it was observed that large numbers of people had been infected and the economic implications of the disease, as a serious barrier to economic development, was greatly felt. Consequently, various scientific committees were formed and dispatched to the field, with very little scientific knowledge of the factors involved in the prevalence of the disease, for investigations into some control measures. Based on apparently *ad hoc* reports and recommendations, some control strategies were embarked upon with the aim of eradicating the disease. Among these were the mass diagnosis and treatment of the disease, preventing people at risk from coming into contact with tsetse flies and the destruction of vegetation (tsetse habitats) and game animals (tsetse food source). These measures were applied to varying degrees and in various combinations in different parts of Africa. The results obtained were equally varied from total failure in most places to eradication in a few. The variety of control strategies that were employed and their successes and failure, were reviewed by Duggan (1970). He pointed out that during all this period, very little attention was given to basic scientific research into a better understanding of the systems involved. However, by 1940, when it was realized that a more complex situation of several tsetse species and parasites was involved, it was concluded that eradication was not possible and that a better scientific understanding was necessary for more effective control.

Thus, by the 1950's more attention was directed towards basic research but the pace was slowed down with the development of insecticides that rekindled the hope of eradication. Allsopp (1984) gave a comprehensive review of the application of insecticides in tsetse control. Although eradication or successful control was achieved in some places with insecticides, re-infestation of control areas (reinvasions) remained a major problem.

The limitations of insecticide application were apparent by the 1970's. In addition to the fact that no permanent control was achieved in most cases, was the high cost of insecticides and associated environmental pollution. Thus the search for alternative control measures was intensified. Considerable research was carried out on the vector behaviour and ecology to provide information for discriminative and selective application of insecticides. Efforts were also put into the search for cheaper and less toxic insecticides and more economical and effective methods of insecticide application.

Several lines of research on control strategies, alternative to the sole use of insecticide, were also embarked upon by various investigators. These included the search for a vaccine against trypanosomes, the breeding of trypano-tolerant animals, the search for biological control agents for the vector, genetic control by the Sterile Insect Technique (SIT), physiological control with Insect Growth Regulators (IGRs) and the development of effective odour-baited traps and insecticide impregnated screens/targets. There have been varying degrees of progress in these fields of research. Jordan (1986) appraised the various approaches and their future prospects. He identified SIT and the use of odour-baited traps and screens/targets as the most promising approaches to vector control.

The SIT involves the release of large numbers of laboratory-bred sterile males into a wild population to compete with the wild males and produce sterile progeny. In theory this approach is most efficient for low density populations since the number of sterile males released should be about ten times (x10) that of the wild males. Field trials of the SIT have, therefore, involved the initial reduction of large tsetse populations with insecticides followed by the release of the sterile males. By this approach, successful control was claimed in Tanzania against *G. morsitans morsitans* (Dame *et al,* 1980) and in Burkina Faso against *G. palpalis gambiensis* (Cuissance *et al*., 1980) and *G. palpalis palpalis* (Politzar and Cuisance, 1982). However, the use of this technique on its own does not appear cost-effective on an area-wide (AW) basis because of the high cost involved in rearing and sterilizing large numbers of male tsetse flies.

The research into developing efficient odour-baited traps and insecticide impregnated screens/targets, appeared to be the most promising approach to tsetse and disease control through a greater understanding of the population dynamics and disease epidemiology (Dransfield *et al*., 1986a). To better achieve this, a multi-disciplinary approach was recommended to gather comprehensive information on all possible aspects of the tsetse/ trypanosomiasis system in a given area. Such information could then be used to build an epidemiological model on which any control strategy could be based. This line has been earnestly pursued by several researchers in various parts of the continent and a great deal of promising results have been achieved.

CHRONOLOGY OF CONTROL CAMPAIGNS

It is worth recounting the chronology of the control campaigns that have occurred up to date; they are grouped into periods referred to, here, as eras. They are; ***the Pre-synthetic insecticide era (1908-1940s), Synthetic insecticide era (1940s-1970s) and Trap/Odour-Bait Technology era (1970s –date).***

Pre-synthetic Insecticide

This era covered the period starting from the turn of the 20th century to the advent of synthetic insecticides. During this period, colonial governments embarked on extensive campaigns, with the aim of eradicating trypanosomiasis and the tsetse fly, through the combination of the following tactics:

- Mass diagnosis and treatment of infections,
- Administration of prophylactic drugs
- Preventing people from coming into contact with tsetse flies
- Quarantining infected patients
- Clearing of bushes (tsetse habitats)
- Killing of wild host animals (reservoir hosts)/tsetse food source, and
- Farmers selecting for trypanotolerant cattle breeds

However for about 40 years very little success was realized and it was obvious that eradication was unachievable whilst considerable ecological damage was being inflicted on the environment by the game and habitat destruction techniques.

The fortuitous discovery of a chemical, Dichloro-Diphenyl-Trichloroethane (DDT), as a very potent insecticide, during the Second World War, marked the end of this era.

Synthetic Insecticide era

This era started with the advent of DDT and other synthetic chemicals. The widely acclaimed success of these as very effective insecticides brought back the hope of eradication. Thus, from the late 1940s to the early 1960s relatively high dosages of DDT and to a less extent another insecticide, dieldrin, were ground-sprayed to almost all accessible tsetse habitats in both eastern and western Africa. The drastic effects of this type of spraying on non-target organisms were soon realized. As more information became available on the localized dry season distribution of the flies and their preferred resting sites, insecticide application became more discriminative. and selective; they were applied only to those parts of the habitat which were essential for dry season survival and to selected parts of the vegetation known to be the preferred resting sites (usually up to 3.5 m above ground).

Throughout the 1970s much attention was focused on helicopter spraying techniques with a view to further refining the discrimination principle and evaluating alternative insecticides which could be less toxic and more degradable than DDT and dieldrin. Nevertheless, by this time, the drawbacks of insecticides in general, and DDT in particular, were becoming more evident to researchers; these included environmental (especially soil and water) pollution, owing to their long lasting (not easily biodegradable) effect and toxicity to non-target and sometimes beneficial organisms, such as fish, birds and other insects. Besides, the cost of these synthetic chemicals was prohibitive, especially with recurrent applications in most situations, which additionally promoted the development of resistance in tsetse populations. The use of insecticides for tsetse control campaigns by researchers and national governments in various parts of Africa has been reviewed by Baldry (1983).

The search for a vaccine was a research mandate of the International Laboratory for Research in Animal Diseases (ILRAD), formally based in Nairobi, Kenya. The search has been abandoned owing to technical (immunological) difficulties and the institute merged with the International Livestock Centre for Africa (ILCA), in Ethiopia, to form the International Livestock Research Institute (ILRI), now focused on developing trypano-tolerant breeds of cattle.

Trap/Odour-Bait Technology Era

This era might be better approached from historical perspective because the usage of traps and attractive screens/targets for tsetse flies are old concepts, techniques and tactics that were abandoned and later revisited. Early colonial investigators used human catchers (‘fly boys') to sample tsetse populations because some tsetse species are attracted to human host (anthropophilic). Thus, a humorously put by Cuisance (1989), ‘man can behave like a predator by catching tsetse using an entomological net’. As such, in small isolated areas, with efficient catching, over a long enough period, one can greatly reduce the density of certain species.

Past Control Campaigns using trapping Techniques

Manual catching was employed on the island of Principe (1910) and on a small island of Lake Victoria (1914). Glasgow and Duffy (1947) eliminated *G. fuscipes* in an area of 3.5 km ×14 km with 24 catchers.

In Sudan ten catchers considerably reduced *G. morsitans* population in the “Koalib Hills” (Ruttledge, 1928 in Buxton, 1955).

Manual catching was soon replaced by trapping systems which were less tedious and more efficient against a number of *Glossina* species which were less anthropophilic.

In 1910 (Maldonado) and 1914 (da Costa) made their plantation workers to wear on their backs, black screens smeared with glue; 133,778 *G. p. palpalis* were caught in 20 months. In 1931 in Zululand, Harris (1938) caught more than 7 million *G. pallidipes* with 487 traps and thus drastically reduced the population. This technique together with the host elimination was close to eliminating tsetse (Jordan, 1986).

Swynnerton (1933-1936) used intensive trapping in Tanzania with the view to eliminate tsetse flies but the traps were not very efficient and the results very poor.

From 1949 to 1960 trials were vigorously mounted against *G. palpalis* and *G. tachinoides* in Ghana, West Africa, Morris (1949) and Morris (1961). He recommended the deployment of 50 traps per hectare impregnated with DDT. In 1961, Morris used his 'animal trap' (animal-shaped) to protect a college and hospital premises in Northern Ghana, by placing them at the fringes of the surrounding vegetation. He reinforced this by dusting and spraying the vegetation with DDT. Descriptions of these early traps are given in an illustrious review by Challier (1977).

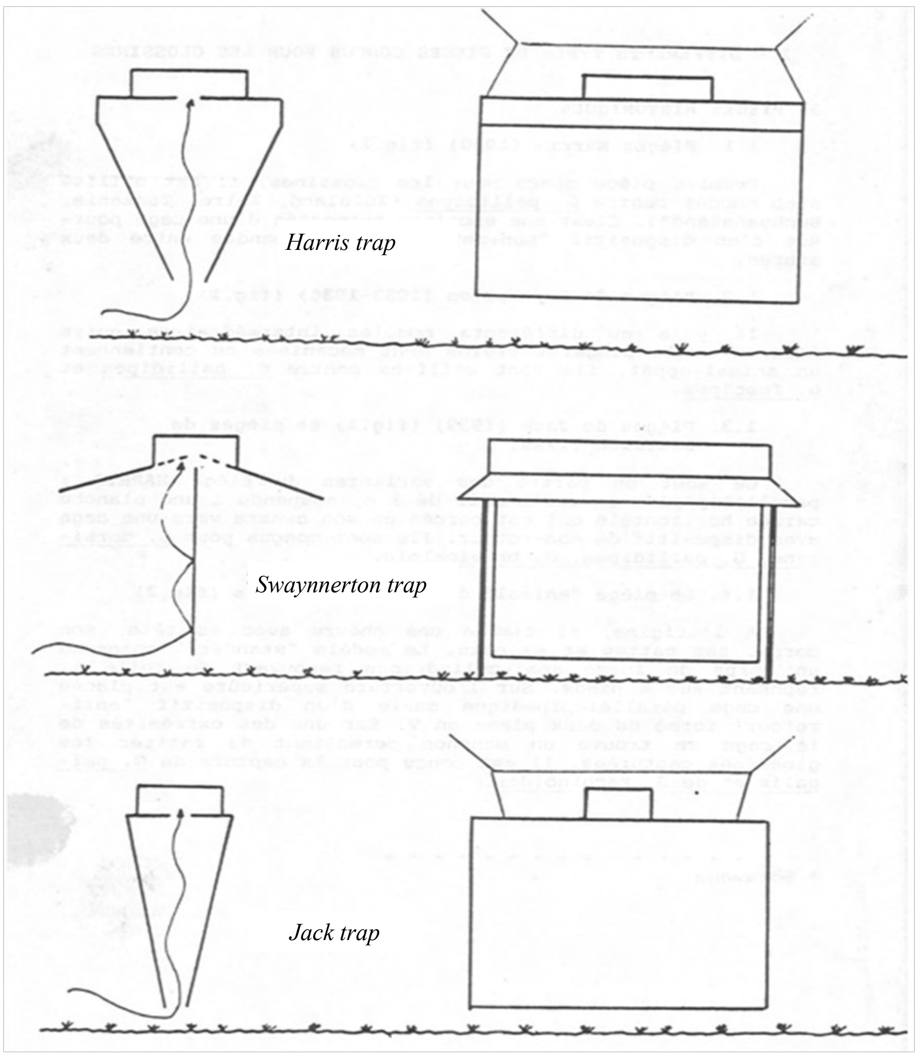

Fig. 1a: Earlier traps (adopted from Cuisance, 1989)

Source: *F.A.O. Training Manual for tsetse control personnel Volume No. 1*
Tsetse biology, systematic and distribution techniques (edited by J.N. Pollock)

As regards to the history of screens/targets, the principle had already been crudely demonstrated on the Principe Island as recounted above. In a more refined way, Rupp (1952) deployed, by hanging across the river Liforo between Rwanda and Burundi, pieces of fabric (50 cm x 140 cm, now referred to as screens/ targets), impregnated with DDT. This resulted in 60% reduction in the population of *Glossina palpalis* and *G. fuscipes* within the first 48 hours following deployment. But the efficiency was limited by reinvasion and deterioration of the efficacy of the DDT. Figures 1a and b are sketches of some of the earlier trap designs, constructed mainly from wooden materials.

The development of more recent traps and screens/targets.

From 1961, trapping technology was forgotten and was not revisited until the findings of Vale et al (1969 -1970) in eastern Africa and Challier et al, (1973) in West Africa. Consequently,

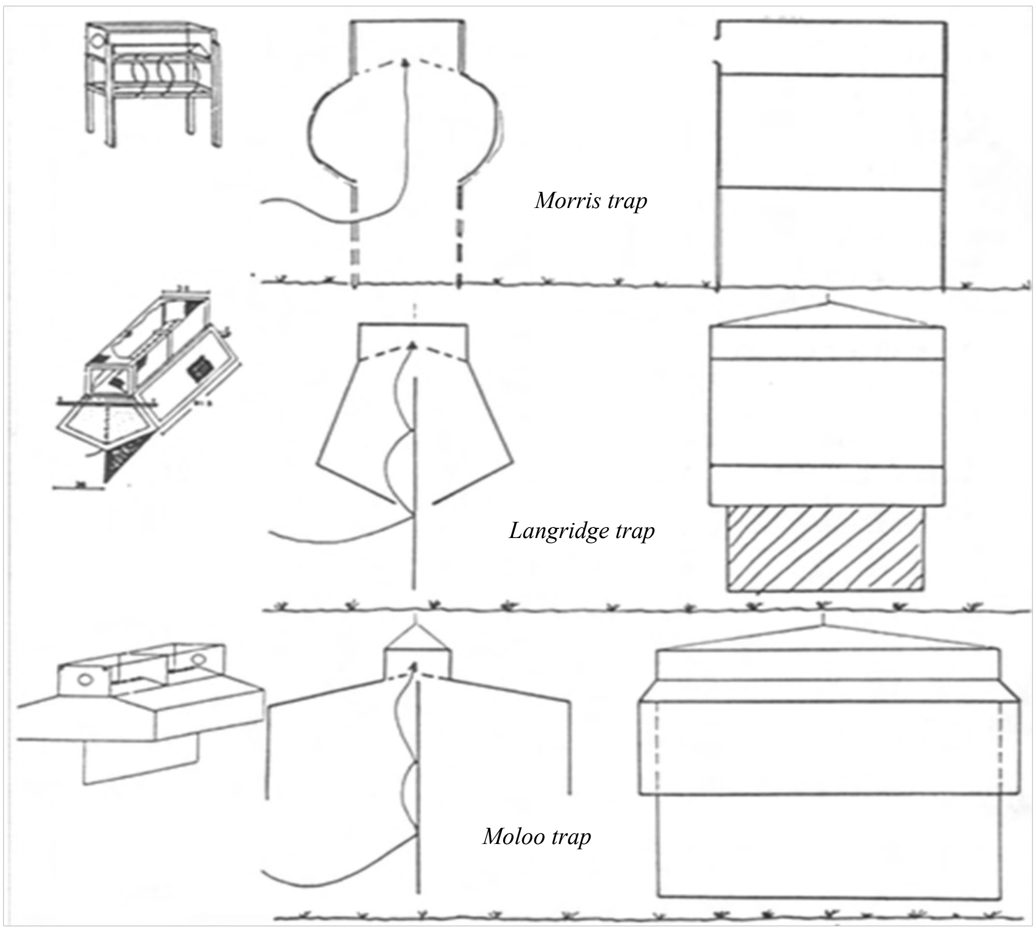

Fig. 1b: Earlier traps continued

Source: *F.A.O. Training Manual for tsetse control personnel Volume No. 1 Tsetse biology, systematic and distribution techniques (edited by J.N. Pollock)*

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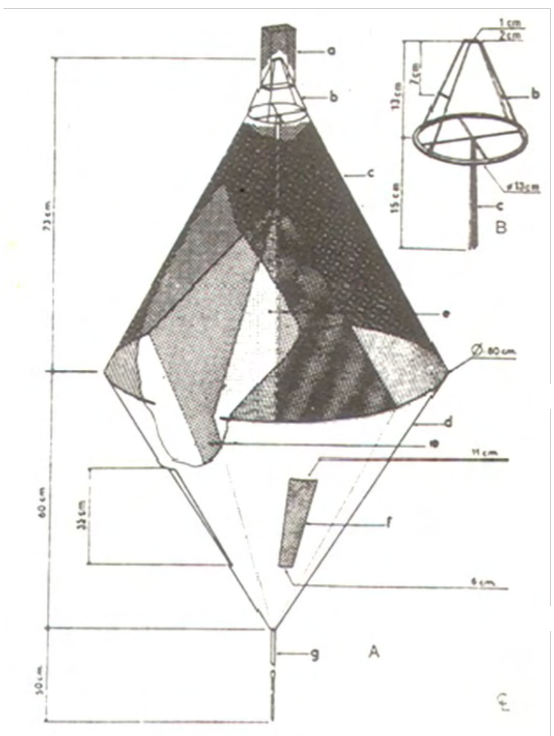
research interest was rekindled in population dynamics and ecological studies. Thus, for about ten years (1970s – 1980s) considerable studies were conducted on the behaviour of tsetse flies with respect to more efficient trap designs and host odour attractants for sampling and control of tsetse populations.

Following the loss of confidence in the reliance on insecticides alone as a control measure, serious research was revitalized and considerable advances were made, especially in the development of traps and odour attractants. Figures 2-8 are sketches of these relatively recent trap/target designs constructed mainly from fabric materials with metal and/or wooden supports.

Three major technological developments have become significant landmarks in this evolutionary process. Firstly, the fabrication of a user-friendly trap, the Challier-Laveissiere biconical trap (Challier and Laveissiere, 1973) revolutionized sampling tsetse populations thus opening up various aspects of investigations especially into tsetse population dynamics and behavioural studies of several tsetse species. As summarized by Cuisance (1989), it was developed in West Africa (Burkina Faso) for sampling *Glossina tachinoides* and G. *palplalis gambiensis*. In later years it was successfully used for *G. pallidipes* in East Africa (Owaga 1980; Turner 1980; Dransfield *et al* 1986a) and also for *G. longipalpis* and *G. m. submorsitans* in West Africa (Cuisance *et al* 1984; Politzar *et al* 1984). It has also been used for species of the *Fusca* group, in Kenya, including *G. longipennis* (Kyorku, 1989) and *G. brevipalpis,* (Dransfield, 1984 and Kyorku *et al*, 1995). Although the trap efficiency varied from species to species considerable information was gathered on the distribution and ecology of important vector species in many parts of Africa. Parasitological and epidemiological knowledge, for several tsetse populations in various parts of the continent, were also greatly improved.



A. Cutaway view of the trap
- a - roubaud cage
- b - opical support
- c - upper cone in plastic tulle mosquito net
- d - inferior cone in white fabric (later blue)
- e - screen in black fabric
- f - lateral aperture
- g - hollow metallic shaft

B - Details of the apical support
- a - aperture giving access to the cage
- b - abutment to support the cage
- c - 4 metallic rods introduced at the top of the shaft

Figure 3: Challier-Laveissiere biconical trap for impregnation with insecticide

Source: *Challier et al., Cah. ORSTOM, Sér Ent. Méd. et Parasit. 1973, II(4), 251-262*

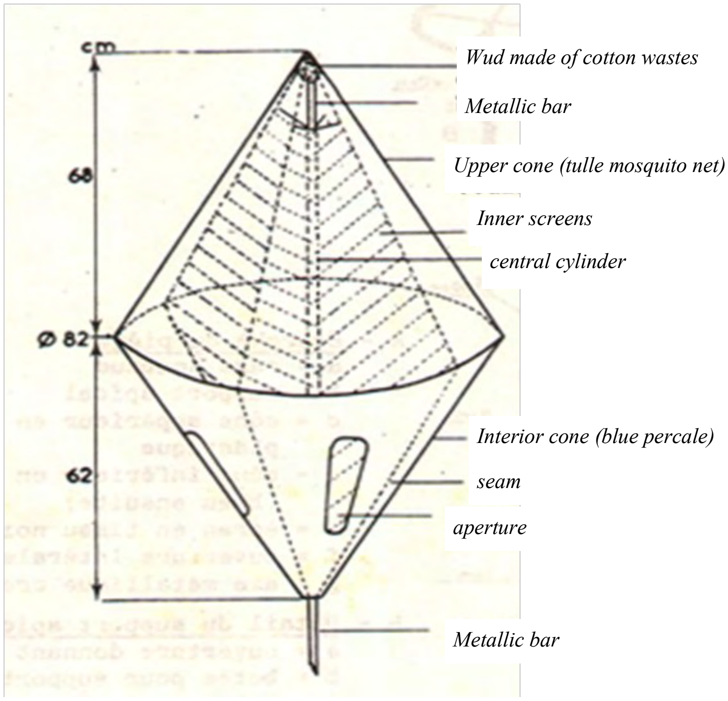


Figure 4: Cubical F3 trap of Flint

Source: *Adapted from Laveissière et al., WHO/VBC 70.746, 1979, 17 p.*

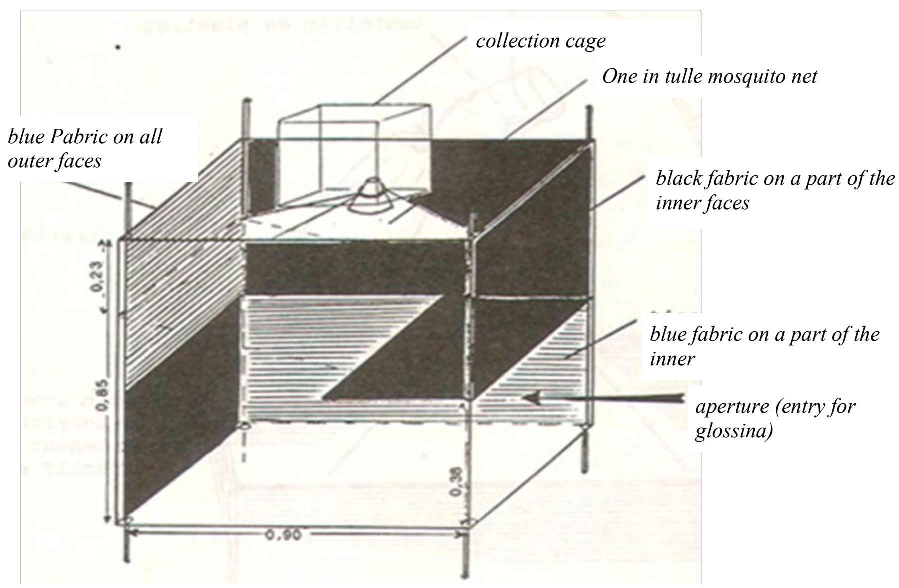


Figure 5: NG 2B trap of Brightwell *et al.*

Source: *Adapted from Flint S., Bull. Ent. Res. 1985, 75, 579-534*

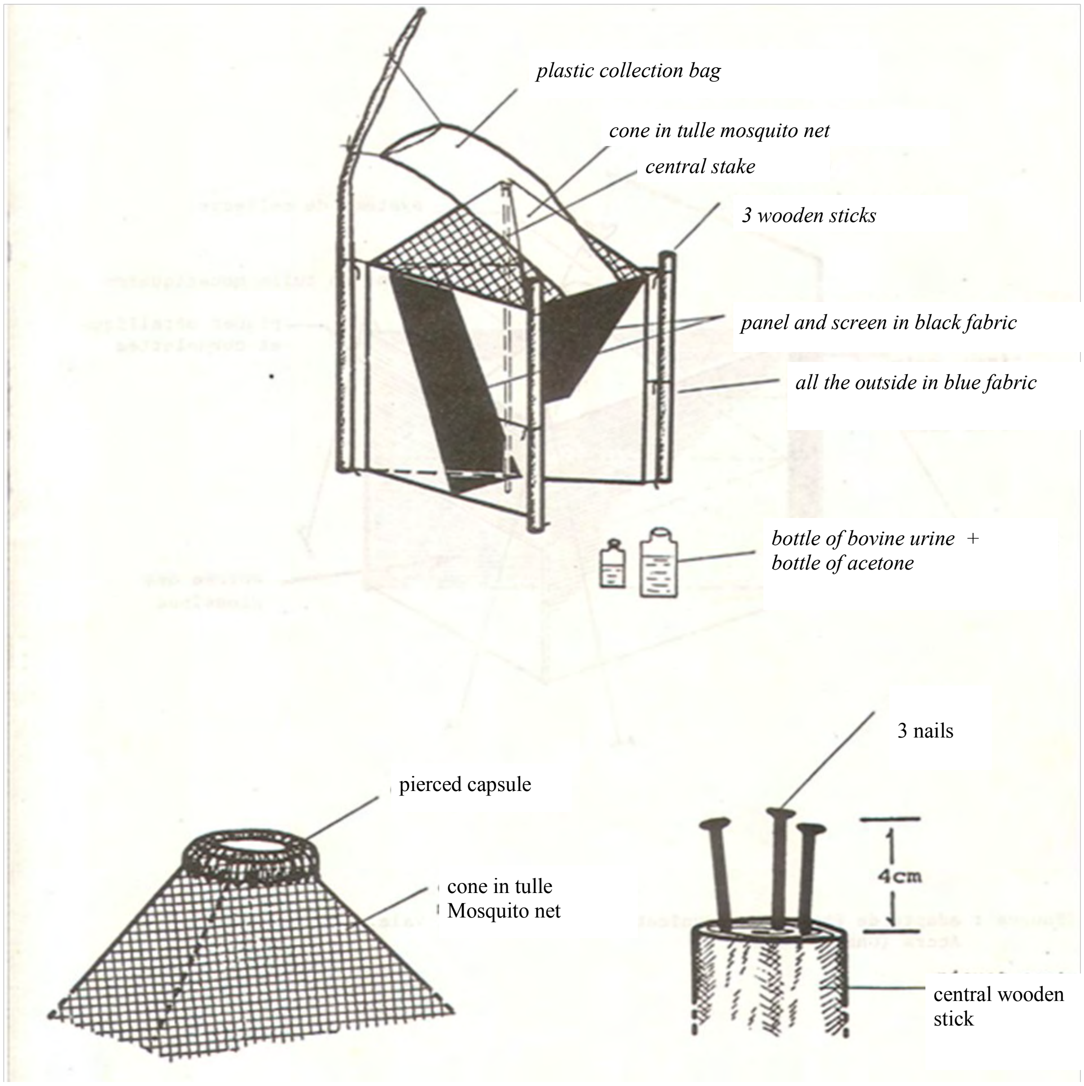


Figure 6: Mobile Screen of Vale

Source: *adapted from Brightwell et al., Tropical Pest Management, 1987*

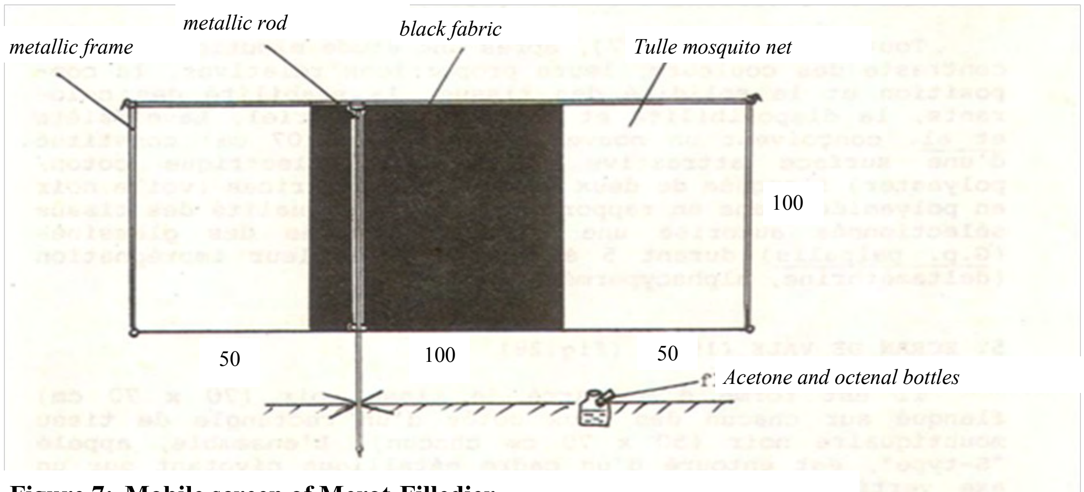


Figure 7: Mobile screen of Merot-Filledier
Source: *adapted from Vale et al., Bull. Ent. Res., 1985, 75, 219-213*

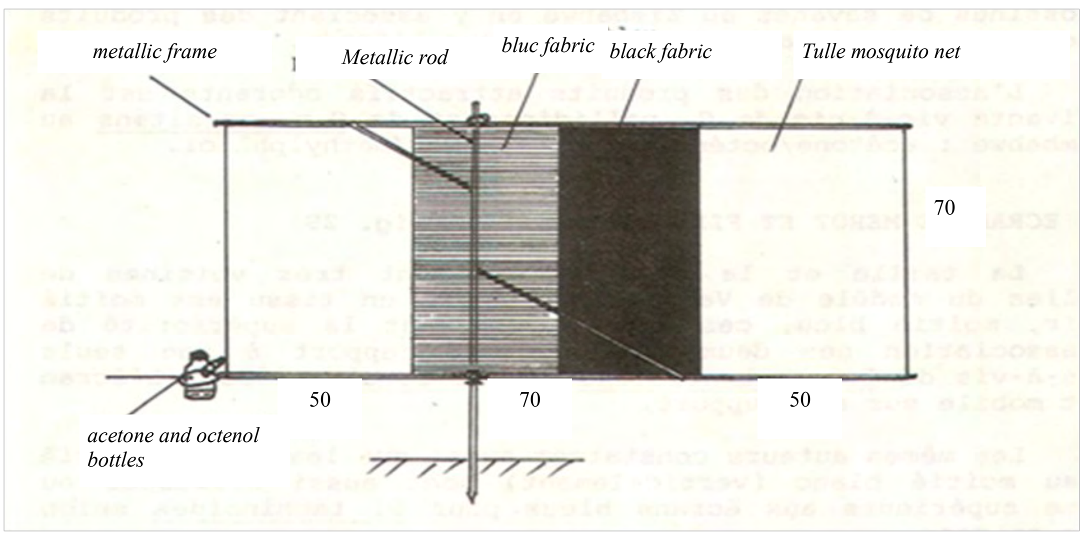


Figure 8: Electric grid of Vale
Source: *adapted from Mérot et. al., 1985, 38(1) : 74-71*

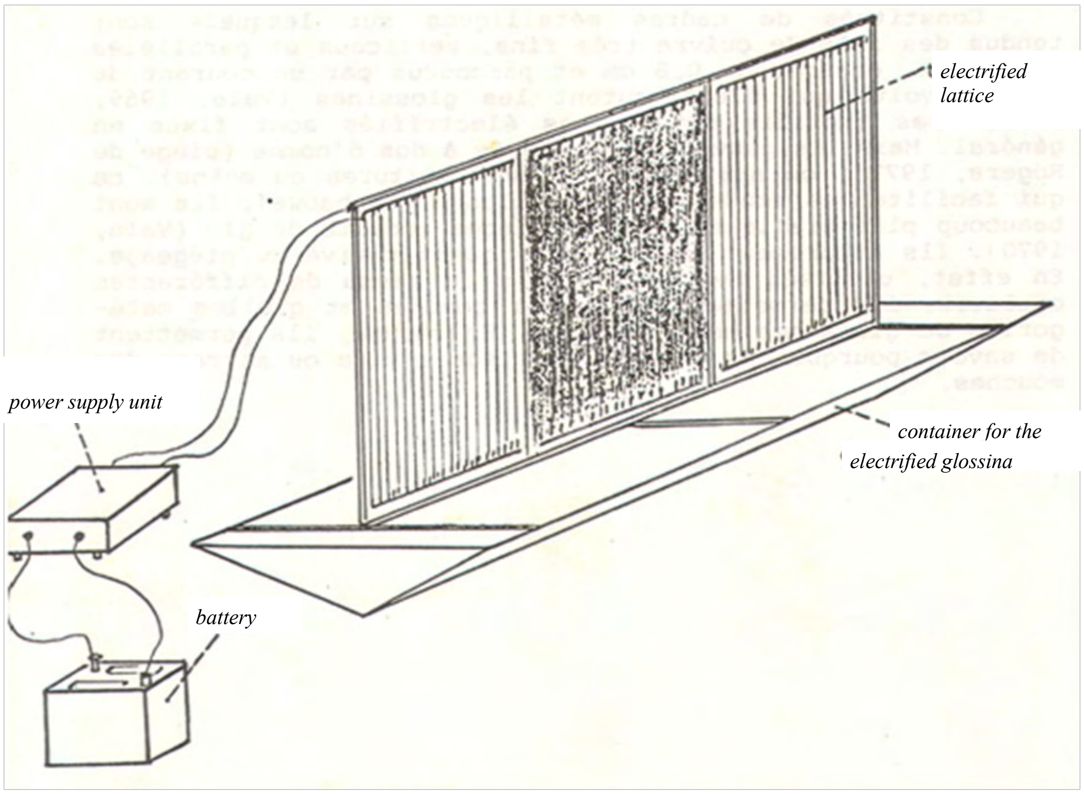


Figure 8: Electric grid of Vale
Source: *adapted from Vale, ent. Res., 1974, 64, 199-208k*
Vale et al., Bull. Ent. Res., 1985, 75, 219-213

Secondly, came the discovery of olfactory (odour) attractants emitted from the bodies of tsetse host animals. Investigators took cues from past observation made by Swynnerton (1936) and Chorley (1948) that tsetse flies aggregate at buffalo resting sites. Based on that, investigators tried baiting traps with different metabolic waste products from various animals to test their attractiveness for different tsetse species. These included cattle breath, carbon dioxide, and acetone by Vale, (1974a, 1979, 1980,) buffalo body washings and urine, by Owaga, (1984, 1985), cow urine by Dransfield *et al.,* (1986b). Based on the observations by Vale (1974a), Hall *et a*l., (1984) identified the attractive active ingredients in cattle breath as carbon dioxide, acetone and 1-octen-3-ol. Hassanali *et al*. (1986.) also identified 1-octen-ol and a number of phenols as the key attractants from cow urine. Saini, (1988) showed through electro-antennogram studies that the volatiles from these animal products are perceived on the antennae of the tsetse fly. More information on other odour-bait investigations undertaken by other researchers are given by Cuisance (1989) and Dransfield and Brightwell (1992).

The third landmark which was almost simultaneous with trap development was the introduction of the use of attractive screens or targets. These are pieces of coloured (mostly blue and/ or black) cotton fabric materials (about1.0 m x 1.0 m) impregnated with insecticide. The attractiveness of blue and black colours had already been empirically demonstrated in the biconical trap design of Challier and Laveissiere, (1973). This was confirmed by Green (1988) through more analytical experiments comparing the landing responses of tsetse flies to various coloured panels baited with odour attractants. He observed that blue, white and red were the best attractive colours and black elicited best landing response. It is important to record that, by this time better environmentally friendly organic-based insecticides such as the pyrethroids had been developed. One of such that has been widely used to impregnate traps and screens/targets is deltamenthrin.

Finally, another important development was the fabrication of killing device known as the electric grid designed by Vale (1974b). It acts as an invisible intercepting system of tiny wires closely set in a 1.0 mm x 1.0 mm grid. In operation it is electrified by ordinary car battery through a High Tension (HT) power pack which can deliver up to 20,000 volts to the grid. When placed by a trap or screen/target and/or odour bait, attracted flies inadvertently fly into the grid and get electrocuted. The device was used for more analytical studies of tsetse behaviour with respect to trap/target or odour bait efficiency. It was, therefore, used in comparing the relative attractiveness of different tsetse species to various killing/catching devices. This led to a proliferation of trap designs of various colours, shapes, sizes and their combinations for various species in different parts of Africa.

Generally, these designs varied with the ingenuity of the investigator(s), the species being studied and the use for which the trap was designed. Some of the most complex traps designs were the Alpha and Beta traps of Vale (1982 a and b) used for analytical studies of fly behaviour at the trap from landing and entry to being caught. Conversely some of the simplest traps, were a variety of traps dubbed "NGU" traps developed at Nguruman, Kenya, by Brightwell *et al*., (1987; 1991) and Kyorku, (1989). They were for sampling *G. pallidipes* and *G. longipennis* and the most efficient model. The NG 2B was ultimately baited with cow urine and acetone and successfully deployed for a pilot control project in the local Masai group ranch area, Dransfield *et a*l. (1990) and Kyorku *et al*. (1990).

As outlined and illustrated by Cuisance (1989), a variety of screens/targets were also developed and used for pilot control campaigns. To list a few, they included those of Challier and Gouteux (1978), Vale (1983), Merot and Fillendier (1985) Laveissiere *et al.* (1986) and Gouteux *et al,* (1987) as shown in figures 6 and. 7. Several more screen types, details of their shapes, sizes, colours and numbers used have been described by Cuisance (1989) and Dransfield and Brightwell (1992) who focused more on the development of trap/odour-bait technology and their application in pilot control campaigns.

Later control campaigns using traps and screens/targets

Alongside the proliferation of new traps and the discovery of odours baits, many pilot control campaigns have been undertaken by a number of investigators using odour-baited traps and or screens/targets. In some cases the trap/targets were impregnated with organic insecticides such as deltamethrin. In 1978 Challier and Gouteux initiated a control campaign against *G. p. palpalis* using screens impregnated with deltamethrin in a sleeping sickness endemic area in Vavova (Cote, d'Ivore). Gouteux *et al.* (1987) also conducted control trials in five Congolese rural communities. Subsequently, several pilot trials with various types of traps and screen have been carried out by various investigators working on various tsetse species in East, West and Central Africa. These are outlined by Cuisance (1989).

Subsequently, Dransfield *et al*. (1990) used the NG 2B trap baited with cow urine and acetone in a pilot control project obtaining 99.9% population reduction in 8 months following trap deployment. Similar results were obtained in most of the other pilot projects mentioned above. These results indicated that the traps/ odour bait developed so far, were efficient and cost-effective enough to significantly contribute to successful campaign against tsetse flies and hence trypanosomiasis. The choice and the integration of control techniques and the economics of control have been elaborately reviewed by Cuisance, (1989) and Dransfield and Brightwell (1992).

The Future; Pan African Trypanosomiasis and Tsetse Eradication Campaign (PATTEC)

Based on the promising results of these cost-effective and environmentally friendly strategies, the African Heads of State took a bold decision on the tsetse and trypanosomiasis situation, at the African Union (AU) summit, held in Lome, Togo, in July 2000. Under the theme "Turning Decisions into Action", they adopted the trap/target technology as the major technique, among others, in a Community-Based Integrated Pest/Vector Management for Area-Wide (AW) tsetse and trypanosomiasis eradication campaign; the Pan-African Trypanosomiasis and Tsetse Eradication Campaign (PATTEC). All African countries infested with tsetse flies are willing parties to this decision. The principle behind the AW approach is to "roll the carpet". This would involve simultaneous control in various parts of Africa with the view to ultimately mopping up all tsetse flies and creating a trypanosomiasis-free area for agro-pastoral development. Details of this continental undertaking are given in PATTEC Documents (Appraisal Report, 2004) and Newsletter (2004).

With this approach, the reinvasion problem, which has hitherto been the major problem in most of the past control trials should, hopefully, be curbed. The prospects of this project are apparently very good, provided the communities are adequately sensitized, educated and organized to participate and take ownership of the projects in their respective areas. The operation would be labour intensive and the community commitment and mobilization would be very crucial to the success of this continental undertaking.

CONCLUSION

Anecdotally, the century long evolution of tsetse control strategies can be likened to the process of Darwinian biological evolution. Present day species of organisms including the human species are the result of continual modification of earlier species through natural selection. Similarly, current control strategies are a result of continual modification of earlier ones through intensive entomological research. Thus, the vestiges of earlier (more primitive) biological species can still be found in present day (more advanced) species. Likewise, the vestiges of earlier control strategies also still exist in current control strategies. Finally, in the biological evolution modern man (*Homo sapiens)* is regarded as the most advanced species so far. The trap/target-odour bait system can also be regarded as the most efficient and cost-effective control tactic so far. It cannot be predicted how long PATTEC will run to effect eradication but judging from how rapid population reduction was achieved in the pilot control projects, positive results are expected in a reasonably short time if all the components of the IPM are well synchronized and effectively maintained all the time.

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