TRAPABILITY OF PERIURBAN POPULATIONS OF HORSEFLIES (DIPTERA: TABANIDAE) IN KHARTOUM STATE, SUDAN

By

M. M. Mohamed-Ahmed, M. A. Abdulla, Y. O. Mohamed, I. E. El Rayah and Y. E. El Amin

Department of Parasitology, College of Veterinary Medicine and Animal Production, Hillat Kuku, P. O. Box 204, Khartoum North, the Sudan.

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ABSTRACT

Experiments were conducted between October 2001 and September 2005 near Khartoum, Sudan to study the trapability of periurban populations of horseflies and Muscidae (Diptera) in canopy, NGU2B, biconical and Nzi traps. The main objective was to develop a simple bait technology to control horseflies. Female *Atylotus agrestis* (Wiedman), *Tabanus sufis* (Jennicke) and *T. taeniola* (Palisot) were the only tabanids trapped. The Nzi trap caught up to 3.0 and 12.0times as many horseflies as the NGU2B and the biconical trap, respectively. The corresponding figures for muscids were 6.6 and 7.0times as many insects. The NGU2B trap captured 4.2times as many *A. agrestis* and 2.2times as many total tabanids as the biconical. There were no significant differences between the Nzi and canopy traps in catches of any one insect species and between the NGU2B and the biconical in catches of muscids or *T. sufis*. Monthly catch indices of the Nzi relative to the biconical suggested that the Nzi trap was highly effective in monitoring declining and/or sparse populations of horseflies. Limited data with the Nzi, biconical and Vavoua traps in central and southern Sudan confirmed the low efficacy of the Nzi against *Glossina fuscipes fuscipes* (Newstead) (Diptera: Glossinidae) and its superiority against diverse species of tabanids including *Philoliche magrettii i*(Wiedman) which has never been caught in a visual trap before. The Absolute efficiency of the unbaited Nzi was 63.8, 55.8, 7.8, 45.3 and 0.5% against *A. agrestis*, *T. sufis*, *T. taeniola*, total tabanids and muscids, respectively. Efficiency was enhanced by dispensing an attractive octenol/phenols blend near traps. The Nzi plus octenol blend odour are possible baits to sample and control horseflies.

INTRODUCTION

Horseflies (Diptera: Tabanidae) are worldwide blood-sucking ectoparasites of farm animals and humans (Balfour, 1906; Foil, 1989). During feeding horseflies transmit to hosts pathogenic viruses (rinderpest), bacteria (haemoragic septicaemia), Protozoa (trypanosomosis) and helminthes (loaiosis) (Foil, 1989). The painful bites of tabanids also influence parameters of fitness in farm animals. These include reduction in: weight gain, milk production, feeding and feed conversion rates, blood, and traction power. Moreover, distraction and irritation by bites predispose animals to accidents and predation (Waage, 1979); bitten and exhausted animals are more susceptible to pathogens (Yagi, 1968).

About 74species of horseflies (local name 'Surret') occur in the Sudan (Lewis, 1953; Mohamed-Ahmed, 1997). Although these flies are important vectors of diseases of humans and livestock their bites on animals are considered the most serious menace in the Sudan and attacked animals may die (Balfour, 1906). Thus, the bites of horseflies dictate the annual northerly migration of Baggara (cattle owning nomads) and other nomads together with wildlife, from their dry season grazing in southern and eastern Sudan to the relatively tabanid-free pastures in the north during the rains between May and November (Bruce, 1790 in Lewis, Anon; Buxton, 1955; Hall *et al.*, 1983). It is a fact that future economic development entails the settlement of nomads (over one third of the population) in areas now evacuated during the tabanid or rainy season (Tothill, 1948). The latter suggestion is internationally relevant because similar tabanid and biting fly problems with ensuing repercussion on pastoralists' welfare persist across sub-Saharan Africa from Somalia to Senegal (Dirie *et al.*, 1989; Hall *et al.*, 1983).

Control of horseflies is extremely difficult (Ford, 1976). However, there is probably still a scope for manoeuver using bait technologies which have recently proved very successful in control trials of tsetse flies (Vale *et al.*, 1988; Dransfield *et al.*, 1990). Control may be attained by employing killing gadgets such as traps, live baits and targets that exploit the visual and olfactory cues used by flies to locate vertebrate hosts, floral nectar and/or honey dew on plants at contact points (tabanid breeding sites and livestock concentration sites). Simple bait technologies are also amenable to community participation which is a key perquisite for durable vector control (Allsop, 1994)

Both tabanids and muscids are known to be attracted to blue targets and traps (Browne and Bennett, 1980; Allan, 1984; Muirhead-Thomson, 1991; Mihok *et al.*, 1995 and in press). These insects are also attracted to whole bovine odour (Vale, 1974a) or its derivatives such as carbon dioxide (CO_2) (Wilson, 1968) 1-octen-3-ol (octenol) (Holloway & Phelps, 1991; Mihok *et al.*, 1995; Krcmar *et al.*, 2005)) and octenol/phenols blend (Foil & Hribar, 1995). Yet, the first step towards devising a successful bait technology is the choice of an effective trap design for sampling and, possibly, control of horseflies. In this paper we compare the effectiveness of five standard tabanid and tsetse traps against tabanids and muscids in Khartoum State, Sudan.

MATERIALS AND METHODS

Study Site: Most studies were conducted between October 2001 and September 2005 in the Experimental Farm Unit of the College of Veterinary Medicine and Animal Production, Sudan University of Science and Technology, Hillat Kuku, Khartoum North (15.5 ° N, 32.5 ° E) Khartoum State, Sudan. About 25 hectares of the farm are utilized for cultivation of fodder. Fodder crops are irrigated by a system of canals originating from the River Nile. These canals constitute permanent suitable breeding sites for horseflies (up to 300 insects/trap/day) and haematophagous Nematocera (Diptera): including mosquitoes, biting midges and sand flies, snails of the genera Lymnaea and Bulinus which are intermediate host of Fasciola gigantica and Scistosoma spp. that cause liver rot and bilharzias of humans and animas. Some 150 experimental animals in the farm comprising cattle, equines and camels guarantee a permanent source of blood meals for haematophagous flies. The main college buildings to the south of the farm are well furnished with exotic evergreen shade trees as well as flower and grass beds that also provide floral nectar, resting sites and refuge for insects during extreme climatic conditions in this largely desert environment. More or less similar settings of periurban farms and irrigation systems with comparable insect fauna are scattered around the perimeter of Khartoum to provide the capital with fresh vegetables, fruits, dairy and poultry products.

Khartoum and its environs have an arid desert climate with three distinct seasons. The cool dry season is from October to April, the hot dry season from April to June and a short rainy season from July to September. The annual rainfall varies between 100-200mm and temperatures may be as high as 49°C in May and as low as 7°C in December/January.

Trapping of Flies: The traps used included a locally-modified portable canopy (Axtell *et al.*, 1975; Abdel Karim, 1980), the biconical (Challier *et al.*, 1977), NGU2B (Brightwell *et al.*, 1987), Vavoua (Laveissiere & Grebaut, 1990), and the Nzi (Mihok, 2002). Unless stated otherwise, all traps were unbaited and were made of imported blue cotton cloth, local white nylon mosquito netting and local matt black cotton cloth. The blue cloth was imported from Kenya (United Textile Industries Nairobi, Kenya) following ICIPE scientists (Mihok, 2002). Traps were sited 100-500 m apart and catches were collected at 24 h intervals. Captured flies were killed by insolation in plastic bags after which they were identified and counted.

Experiment I: Effect of season on trap catches of horseflies and muscids in Khartoum State. Preliminary comparisons at Hillat Kuku, Khartoum North, in June 2001, showed that the Nzi trap was far more effective against tabanids and muscids than the biconical trap. To examine whether such differences between traps are consistent over seasons together with information on seasonal availability of flies to traps, the two designs were compared by a set of 2×2 Latin squares replicated twice each month from October 2001 to September 2002.

Experiment II: Comparisons of the Nzi with canopy, NGU2B and the biconical traps in Khartoum State. Using 4×4 Latin square designs replicated twice, the portable canopy, the biconical, NGU2B and the Nzi traps were compared for their effectiveness against horseflies and muscids at Kuku, Khartoum North in September 2004.

Experiment III: Efficacy of the Nzi against G.f. fuscipes. The Nzi trap is a multipurpose for optimal catches of diverse species of biting flies but was reportedly relatively ineffective against riverine tsetse (e.g. *G. f. fuscipes*, Mihok 2002). To confirm this, and observe the efficacy of the Nzi against tabanids and muscids in a comparatively extensive habitat, we compared the Nzi trap with the biconical trap (Challier *et al.*, 1977) and two modifications of the latter trap in southern Sudan where *G. f. fuscipes* coexists with several species of tabanids and muscids (Mohamed, 2004). The biconical trap and the Nzi were made from identical fabrics as described above. Modification 1 (M1) of the biconical was basically the original biconical, but with the upper cone sewn from black nylon netting. Modification 2 (M2) was similar to M1 but the lower cone was made from heavy blue cotton drill borrowed from the Entomology Unit, FAO-IAEA Sieberdorf Laboratories, Vienna, Austria. The traps were compared by 4×4 Latin square experiments replicated twice during January 2003 (hot dry period) in a riverine tsetse habitat near Juba town (5°N, 31.5°E) along River Bahr El Jebel, Southern Sudan.

Experiment IV: Efficacy of the Nzi against stable (Diptera: Muscidae) flies and Philoliche magrettii. A fourth experiment was performed during the rainy season in September 2005 near Damazin town (12.5°N, 34.5°E) Blue Nile State, central Sudan using the Nzi, the biconical and Vavoua traps. The area was chosen because exploratory catches in the Nzi and biconical traps within the provincial Veterinary Research Laboratory in August indicated the presence of a high population of stable flies and a few of the horsefly *P. magrettii*. The Vavoua trap was included because of its proven effectiveness against stable flies (Mihok *et al.*, 1995). The experimental design was 3×3 Latin square replicated twice.

Experiment V: Nzi trap absolute efficiency against tabanids and muscids in Khartoum State Two experiments were performed in August 2005 at Kuku, Khartoum North, to estimate the absolute efficiency of the odour-baited and the unbaited Nzi trap against tabanids and muscids. Absolute efficiency is defined as the proportion of flies caught from the total attracted to the trap (Vale & Hargrove, 1979). Two newly-made Nzi traps were employed using 2×2 Latin square designs in two consecutive separate experiments each replicated twice (one with an octenol/phenols blend as odour attractant and the other without). In each experiment, the traps were set about 500m apart at fixed sites in the fodder plots. One trap was flanked by two electric nets (effective electrocution netting 1.5×1.5 m, Bonar Industries, Harare, Zimbabwe) and the other was left without nets (Mohamed-Ahmed & Mihok, 1999). The nets were alternated between sites each day for four days in each experiment (2replicates). On each day the experiment was run from 1300-1800h to coincide with the peak diurnal activity of tabanids (our unpublished data). The attractive octenol blend was 1-octen-3-ol (octenol), 3-n-propylphenol and p-cresol at 4: 1: 8 ratio (Chemical and Pharmaceutical Ltd, H-1025, Budapest, Hungary). The odour was released from small open glass vials (height, 5cm, internal diameter, 1.5cm) placed under the trap with nets and the trap without nets. The release rate of the octenol blend varied between 0.5-2 mg/hour. Flies electrocuted with the nets were retained in shallow trays containing soapy water. The catches of the trap with nets plus the number of electrocuted flies were taken to represent the total number of flies attracted to the trap (Vale *et al.*, 1986). The catch of the trap without nets was assumed to represent the number of insects actually caught from those attracted to the trap without nets. By dividing the back-transformed mean number (see below) of insects caught in the trap without nets by the back-transformed mean number of the total attracted (electrocuted + trapped insects), trap efficiency with and without an odour bait was estimated as a percentage (Vale *et al.*, 1986; Dransfield *et al.*, 2001).

Experimental Designs and Data Analyses: 2×2, 3×3 and 4×4 randomized Latin square designs incorporating the effects of treatments, sites and days were used throughout. The daily insect catch (n) including those obtained in the efficiency experiments was transformed to $\log_{10}(n + 1)$. Catches in each experiment were compared by analysis of variance. Means were separated using the Student-Newman-Keuls (SNK) test at $P < 0.05$. The back-transformed mean test-trap catch divided by the biconical trap back-transformed mean catch represented the catch index. Back-transformed means or indices alone are presented. Since the SNK test was used to separate means, standard deviations are not presented with means to preserve clarity.

RESULTS

Species of Trapped Flies in Khartoum State: Many dipteran species including horseflies and Muscidae were caught in the Nzi and biconical traps near Khartoum. Although male horseflies were intercepted by electric nets (82males, experiment V) and netted off trees (117males, unpublished data), only females were caught in traps, irrespective of trap type or season. Out of the 1608 trapped tabanid females in experiment I, *A. agrestis* comprised 62.9%, *T. sufis*, 34.1% and *T. taeniola* 3.0%. Of the Muscidae, only the non-biting Muscinae were captured of which 60-90% were *Musca domestica* (Linnaeus)

I. Effects of Seasons on Trap Catches in Khartoum State: Regardless of season or species, the Nzi trap caught more tabanids and muscids than the biconical (Fig. 1 a, b, c, d). Very few *T. taeniola* were caught, and then only in the Nzi trap.

The monthly catch indices of the Nzi trap relative to the biconical are presented in (Table 1). For *A. agrestis*, the highest indices (9.37X mean catch of the biconical; $P<0.05$) were obtained during January, April ($P<0.02$), May ($P<0.03$) and November ($P<0.05$). Considering *T. sufis*, the indices were very high during the hot dry season between March and June (up to 25.0 X; $P<0.0009$), and at the end of the rains in September (11.6 X; $P<0.03$). Indices for total tabanids including *T. taeniola* were, at least, twice as many as those caught in the biconical in any one month and were up to 11.5 times as many in May ($P<0.03$). Indices for muscids were high during the cool dry season from November to March (P down to < 0.006) and at the end of the rains in September when up to 13.7 index was recorded ($P<0.003$).

Table (1): Monthly catch indices of tabanids and muscids of the Nzi relative to the biconical trap, from October 2001 to September 2002, at Hillat Kuku, Khartoum North, Sudan (assuming biconical trap catch = 1)

	Catch index			
Month	***A. agrestis***	***T. sufis***	**Total tabanids**	**Total muscids**
O	2.04	9.61^{s1}	3.69^{s5}	2.32
N	6.33^{s5}	4.35	7.58	2.92^{s1}
D	5.68	0.78	4.11	5.68^{s1}
J	9.37^{s3}	-	4.60^{s3}	4.60^{s4}
F	-	1.34	4.34	6.82^{s5}
M	2.95	17.79^{s7}	7.09^{s6}	6.87^{s2}
A	6.13^{s5}	24.98^{s7}	7.95^{s5}	2.29
M	8.35^{s1}	13.49^{s1}	11.46^{s5}	2.17
J	2.98	10.23^{s6}	2.87	3.93
J	5.23^{s2}	5.87^{s4}	5.42^{s2}	2.05
A	1.12	4.14	1.52	2.99
S	3.87	11.55^{s1}	6.03^{s2}	13.67^{s6}

- = index was not computed because the biconical trap catch = 0, ^{s1} to ^{s5} = index is significantly different from unity at P < 0.01, < 0.02, < 0.03, < 0.04 and < 0.05, respectively. ^{s6} = $P < 0.003$, ^{s7} = $P < 0.0009$.

Regards seasonal fluctuations in catches, the Nzi catches of both *A. agrestis* and *T. sufis* were low in the coolest months of the year, December/January. From February onwards, catches increased with peaks of *A. agrestis* in May, July, September and October (Fig. 1a). Catches of *T. sufis* peaked in March, May, September and October (Fig. 1b). The pooled tabanids showed three dominant peaks: in May, September and October (Fig. 1c). Unlike tabanids, muscid catches in both traps exhibited two similarly-timed, but unequal peaks: the first was in May and the second in November (Fig. 1d). Catches of muscids were low during the cool season from January to April and were lowest during the rains from July to September.

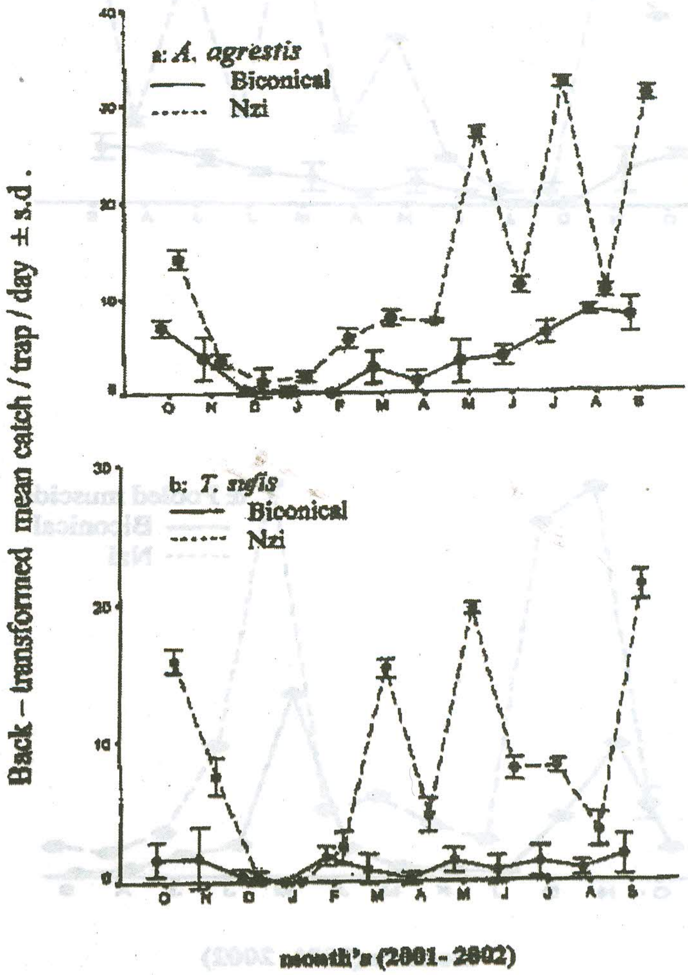
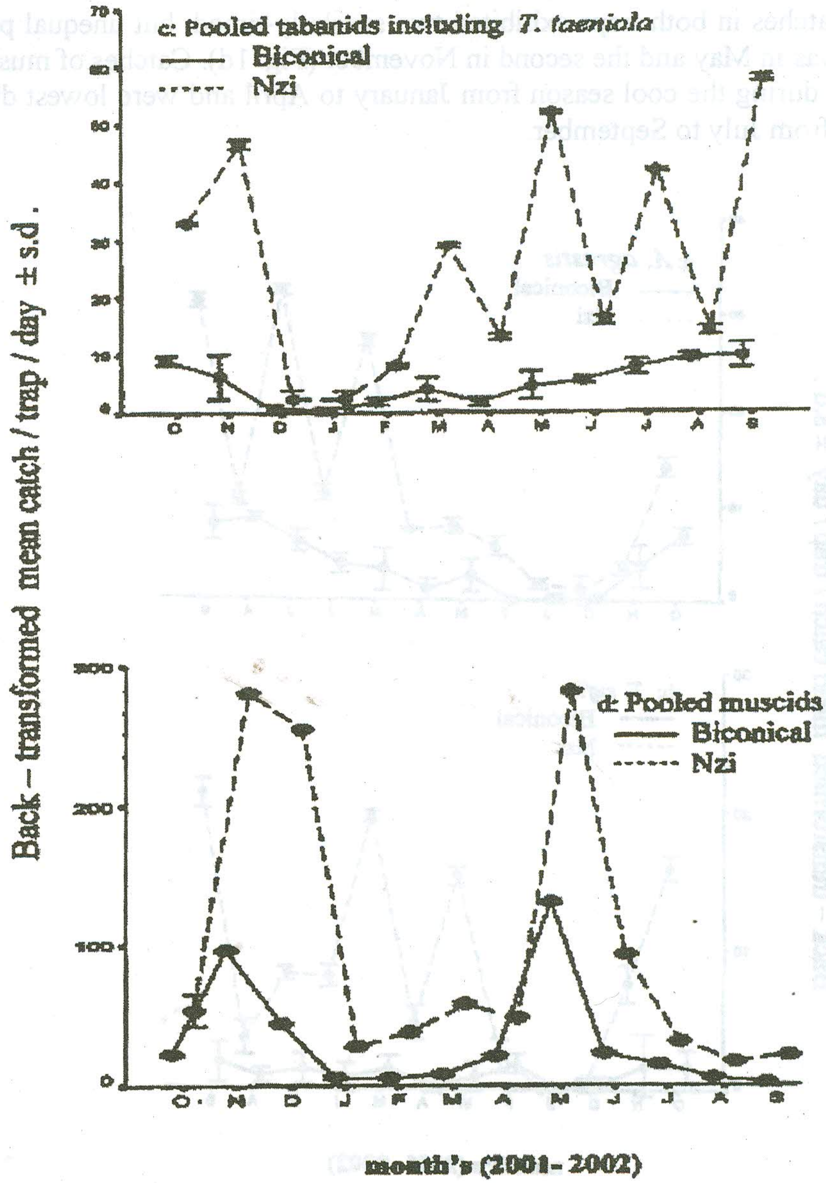


Fig. (1): Monthly fluctuations in biconical and Nzi trap catches of tabanids and muscids, from October 2001 to September 2002 in Khartoum State, Sudan


c: Pooled tabanids including *T. taeniola*
Biconical
Nzi
d: Pooled muscids
Biconical
Nzi
Back – transformed mean catch / trap / day ± s.d.
O N D J F M A M J J A S
month's (2001- 2002)

II. Comparisons of the Nzi with the biconical, NGU2B and canopy traps in Khartoum State: Comparisons between the biconical, Nzi, canopy and NGU2B traps in Khartoum State (Table 2) showed no significant differences between the Nzi and canopy in catches of any one species of Tabanidae or total Muscidae. However, compared with the biconical, the Nzi trap caught significantly more *A. agrestis*, (11.19X), *T. sufis* (4.19X), total tabanids (7.27X) and Muscids (7.04X). The Nzi also caught significantly more *A. agrestis* (2.60X), *T. sufis* (3.84X), total tabanids (3.29X) and muscids (6.62X) than the NGU2B trap. The NGU2B caught statistically more *A. agrestis* and total tabanids than the biconical trap (Table 2). No significant differences were observed between the biconical and NGU2B trap in catches of *T. sufis* or Muscinae (Table 2).

Table (2): Back-transformed means catches of tabanids and muscids in biconical, Nzi, canopy and NGU2B traps at Hillat Kuku, Khartoum North, Sudan (September 2004)

Trap	*A. agrestis*		*T. sufis*		Total tabanids*		Muscids	
	Mean	Index	Mean	Index	Mean	Index	Mean	Index
Biconical	2.9[a]	1.00	2.7[a]	1.00	5.9[a]	1.00	3.2[a]	1.00
Nzi	28.3[b]	11.19	11.4[b]	4.20	43.1[b]	7.27	22.2[b]	7.04
Canopy	27.3[b]	10.63	9.2[b]	3.39	36.0[b]	6.08	13.4[b]	4.24
NGU2B	10.9[c]	4.23	3.0[a]	1.09	13.1[c]	2.21	3.4[a]	1.06
F-ratio	19.4		11.9		22.0		27.2	
P	< 0.00009		<0.0008		< 0.00005		< 0.00002	

Means in the same column with different superscripts are significantly different at the stated probability *P*. * including *Tabanus taeniola*.

III. Efficacy of the Nzi and the biconical traps against G. f. fuscipes in southern Sudan: In southern Sudan, several species and genera of tabanids were caught including *Tabanus gratus* Loew, *T. taeniola, T. pars* Walker, *T. sufis*, and *A. agrestis, Ancala* Gray, *Chrysops* Meigen. and *Haemtopota* Meigen. altogether with a few stable flies, many non-biting muscids and *G. f. fuscipes*. The performance of the Nzi trap was extremely poor against *G. f. fuscipes* (male + female). Thus, the biconical or any of its modifications caught up to 10-22.5 times as many tsetses as the Nzi (Table 3). Conversely, with tabanids and muscids, the Nzi was significantly better than the biconical designs despite the insignificant differences between catches of the grouped Muscidae and *T. taeniola* (Table 3).

Table (3): Back transformed mean catches of *G .f. fuscipes*, tabanids and muscids using Nzi and biconical traps and two modifications of the biconical trap, near Juba town, Bahr El Jebel State, southern Sudan (see text for abbreviations)

Treatment	*G .f. fuscipes*		*T. taeniola*		*T. gratus*		Tot. tabanids		Muscids	
Trap	Mean	Index	Mean	Index	Mean	Index	Mean	Index	Mean	Index
Nzi	0.19[a***]	1.00	1.63[a]	1.00	6.01[a***]	1.00	11.58[a*]	1.00	3.84[a]	1.00
biconical	2.01[b]	10.62	0.65[a]	0.40	0.49[b]	0.08	2.38[b]	0.21	1.03[a]	0.27
M1	4.26[b]	22.50	1.42[a]	0.86	2.30[bc]	0.38	5.51[a]	0.48	1.57[a]	0.41
M2	2.21[b]	11.69	0.30[a]	0.18	1.06[bc]	0.18	2.29[b]	0.20	2.00[a]	0.52

Means in the same column with different superscripts are significantly different at the stated probability P. * F = 6.74, $P < 0.007$; ** F = 9.03, $P < 0.003$; *** F = 16.15, $P < 0.0002$.

IV. Efficacy of the Nzi, the biconical and Vavoua traps against P. magrettii and stable flies in central Sudan: At Damazin, central Sudan catches of horseflies included *A. agrestis, A. fuscipes, P. Magrettii, T. sufis, T. taeniola, T. gratus* and *Ancala* spp. Of the muscids, stable flies (*Stomoxys* spp) and Muscinae were caught. *A. agrestis, P. magrettii* and stable flies were caught in adequate numbers to warrant separate statistical analyses (Table 4). The Nzi caught at least 80, 2 and 3times as many *P. magrettii, A. agrestis* and total tabanids, respectively, as each of the biconical or Vavoua traps. The Vavoua was significantly less effective than the biconical trap against *A. agrestis* (0.35X) and total tabanids (0.35X). However, both of the latter traps caught more than 2 times more stable flies than the Nzi, although the increases were insignificant (Table 4).

Table (4): Back-transformed mean catches of tabanids and stable flies in Nzi, biconical and Vavoua traps near Damazin, central Sudan (September 2005)

Trap	*P. magrettii*		*A. agrestis*		Total tabanid		Stable flies	
	Mean	Index	Mean	Index	Mean	Index	Mean	Index
Biconical	0.1[a]	1.00	14.7[a]	1.00	17.3[a]	1.00	28.3[a]	1.00
Nzi	9.89[b]	80.75	29.8[b]	2.02	51.6[b]	2.99	12.1[a]	0.43
Vavoua	0.12[a]	1.00	5.2[c]	0.35	6.0[c]	0.35	34.4[a]	1.22
F-value	30.7		8.1		24.2		2.9	
P	<0.006		<0.05		<0.008		<0.2	

Means in the same column with different superscripts are significantly different at the stated probability P.

V. Absolute efficiency of the Nzi trap: Estimates of the Nzi trap absolute efficiency with and without octenol blend odour attractant for each species of tabanids, pooled tabanids and pooled muscids are presented in (Table 5). The effectiveness of the unbaited Nzi trap increased in the ascending order of muscids < *T. taeniola* < pooled tabanids < *T. sufis* < *A. agrestis*. The octenol blend attractant improved trap efficiency against all insect species in (Table 5), except *T.*

taeniola. Additionally, many male tabanids were intercepted by the electric nets (59 *T. taeniola*, 9 *A. agrestis* and 14 *T. sufis*), but none was trapped in the Nzi.

Table (5): Back-transformed mean catches of tabanids and muscids and estimates of % absolute Nzi trap efficiency with and without octenol/phenols blend olfactory attractant (August 2005, Hillat Kuku, Khartoum North, Sudan)

Treatment	Mean catches of inserts and % trap efficiency				
	A. agrestis	*T. sufis*	*T. taeniola*	Total tabanids	Muscids
Trap + 2 N	49.1	52.7	37.0	140.3	548.7
Trap alone	31.4	29.4	2.9	63.6	2.6
Trap efficiency (%)	63.8	55.8	7.8	45.3	0.48
Trap +2 N + O	62.1	95.5	27.8	189.6	153.9
Trap + O	63.6	63.6	1.8	137.0	4.8
Trap efficiency (%)	102.4	66.6	6.4	91.4	3.1
Improvement due to attractive odour (%)	38.6	10.8	-1.4	46.1	2.6

2N, 2electric nets, O , Octenol/phenols blend olfactory attractant.

DISCUSSION

Essentially, the discussion of the above results should encompass three inter related concepts. These are i) the socioeconomic circumstances of the underdeveloped African countries and their impacts on parasitic diseases of humans and their animals, ii) entomology and iii) control of insect disease vectors. Like many other capitals of the underdeveloped countries, Khartoum has recently become the ultimate destination of many Sudanese people. For instance, it is a safe haven for refugees and war-displaced people from the South, East and the West. Drought of the early1980s had also sent waves of starved children and women as well as men to the capital, mainly from the western states, Kordofan and Darfur. Industries modern or otherwise seeing the opportunity of cheap migrant labour around, have bloomed in Khartoum, making the city the target of prospective job seekers and their dependents. What is currently dubbed as 'the high education revolution' has focused on the capital, thus swelling the numbers of students and graduates searching for better education and jobs. In consequence, Khartoum's initial two million population has probably surpassed seven million over the last 20years. Such soaring numbers of citizens are certainly in bad need for fresh vegetables, fruits and animal products. This is, probably, the main reason behind the ever-flourishing agriculture around the city with concomitant toll on animal and public health, security and ailing infrastructure. Currently, more land is being surveyed and allotted for farms. Thus periurban farming is and will be on the increase in the foreseeable future. Therefore, as a compromise, we propose the immediate introduction of sprinkler irrigation instead of the conventional irrigation canals to curtail the breeding sites of mosquitoes, snails, horseflies and other disease vectors.

Out of seven species of Tabanidae reported by Lewis (1953) in Khartoum vicinity, only three, namely, *A. agrestis*, *T. sufis* and *T. taeniola* have been trapped in the present work. However, both male and female *T. gratus* were netted by us off trees. Thus, of the earlier tabanids (Lewis, 1953) only *P. magrettii, A. fuscipes* and *Ancala Africana* remain undetected. The most likely explanation for this discrepancy in extant species is that the study area is, probably, not the natural habitat of these horseflies. This may be true because the collections of (Lewis, 1953) included tabanids from various types of vehicles arriving in Khartoum suggesting that some species might not have been indigenous to the area. The latter inference is supported by the recent findings of Mohamed-Ahmed (1997) who worked in a similar habitat near Soba, Khartoum South and caught only *T. sufis, A. agrestis* and *T. taeniola* in traps.

There are many difficulties in trapping biting flies and some research has indicated that there are behavioural differences between populations of the same species 10km apart (Odulaja *et al.*, 2001). Climate, season, time of day and density of flies may further interfere with trap performance. Trap effective-ness is also dependent on fly activity level, diffusion/clumping of a fly popul-ation in the area and the attractiveness of the trap. Initial attraction involves flies moving in from a distance to the proximity of the trap. A final score includes the fly entering the trap and progressing upwards to become permanently locked in the non-return collector at the top. Likely changes in one or more of the above variables may militate against obtaining similar results using one trap design in different environmental settings. Yet, the numbers of Tabanidae and Muscidae caught in the various trap designs in the present study are generally in close agreement (depending on design) with those of previous workers in the Sudan and elsewhere (Abdel Karim, 1980; Mohamed-Ahmed, 1997; Suliman, 1992 Mihok *et al.*, 1995, Mihok, 2002).

Most notable, in the present data, is that the superiority of the Nzi to the NGU2B and the biconical traps against tabanids and non-biting muscids, though not stable flies (Mihok, 2002) has been confirmed. On the other hand, the high Nzi trap catches of *A. agrestis* and *T. sufis* near Khartoum should not entirely be interpreted as a reflection of a relatively high abundance/availability of these species in the area, but should also be attributed, at least in part, to their higher capture efficiency in the Nzi (Table 5). Similarly, the complete lack of capture of *T. gratus* together with the low catches of *T. taeniola* might be ascribed to their low capture efficiency in the Nzi rather than to their low density and/or availability to traps. Even in southern and central Sudan the Nzi failed to catch significantly more *T. taeniola* than the biconical trap (Table 3); and such low efficiency could not be rectified by dispensing an attractive octenol blend (Table 5).

The low catches of all tabanid species in the coolest months of the year (December to February; Fig. 1) might have been caused by the low temperatures in this season. Our unpublished data have already indicated that catches of *A. agrestis*, *T. sufis* and total tabanids in Nzi traps are significantly positively correlated with ambient temperature. The low catches may also suggest an over-wintering phenomenon involving a considerable proportion of larvae of these insects. Denlinger (1978) working in Nairobi National Park observed a paucity in catches of flesh flies (Diptera: Sarcophaginae) in Malaise traps during the coldest months in Kenya, June and July; he attributed this to cold-induced pupal diapause. The low catches of muscids during the rains were unexpected and were probably caused by the routine annual aerial spraying of house flies and mosquitoes in July/August using Malathion. The spray might also have caused the low catches of tabanids during August (Fig. 1, a, b, c). Alternatively, the low catches of muscids might have been an artifact because flies had many available feeding, breeding, and resting sites during the rainy season which, probably, diverted them from the trap. The poor performance of the Nzi against *G. f. fuscipes* (Table 3) though difficult to explain, it confirms the findings of (Mihok, 2002) who observed that the trap was not as effective against riverine tsetse as it was against tabanids, muscids or savanna tsetse.

Estimation of trap absolute efficiency (Experiment V) assumes that attracted flies are either intercepted by the electric nets or otherwise become trapped (Vale & Hargrove, 1979). It also assumes that attracted flies do not fly over or avoid the nets and that electrocution efficiency is nearly 100% (Vale, 1974b).

However, for tsetse flies, recent research has indicated that male and female *G. f. fuscipes* near Lake Victoria, Kenya see and get repelled by the nets and flies fly over the nets when repelled (Odulaja & Mohamed-Ahmed, 1997). Similarly, Dransfield *et al.*, (2001) inferred that *G. pallidipes* Austen at Nguruman, Kenya see the nets and therefore avoid them. Packer & Brady (1990) and Griffiths & Brady (1994) have already shown that electrocution efficiency against *G. pallidipes* and *G. morsitans orientalis* Vanderplank in Zimbabwe is just about 50%. Although the behaviour of tabanids and muscids near electric nets has yet to be studied in such details their response to the device is not expected to depart significantly from that of tsetse flies. Hence, the impossible finding that baited Nzi trap efficiency was more than 100% against *A. agrestis* (Table 5) might have resulted from unanticipated natural insect behaviour patterns (e.g. avoiding and/or flying over the nets, see Dransfield *et al.*, 2001) on the one hand and the innate inefficiency of the electric net on the other.

The main objective of the present studies is to develop a simple bait technology for sustainable control of horseflies and possibly other biting and nuisance flies associated with farm animals and humans. In this context the advantages of the Nzi trap as a sampling and control device of horseflies are obvious. (1) The trap is effective against diverse species of tabanids in diverse environmental settings including *P. magrettii* which has never been caught before in a visual cloth trap other than the Nzi (Abdulla and El Malik, 2003; Phelps & Holloway, 1992; Mihok, 2002). (2) The high indices of increase of the Nzi relative to the biconical trap at low tabanid densities (Table 1) suggest that the Nzi has a higher monitoring efficacy against declining and sparse populations of horseflies. (3) The trap is much more economical in terms of required materials than the conventional tabanid trap, the canopy, which has similar catching efficiency. (4) The trap is easy to make, it could be tailored and sewn by trainees following instructions for 30 minutes or less. (5) The Nzi has the extra advantage of being very effective against savanna tsetse (Mihok, 2002) and (6) our unpublished data has indicated that the performance of the trap against tabanids could be quadrupled by dispensing olfactory attractants such as the octenol/phenol blend (see above) near traps. Thus, the Nzi trap together with octenol blend or, probably, octenol alone (French & Hagan, 1995; Kcmar *et al.*, 2005) as an olfactory attractant may prove effective baits to control tabanids across the globe and locally in periurban dairy farms around Khartoum or nationwide at gathering and watering sites of nomadic and rural livestock.

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