Global Journal of Medical Research: G
Veterinary Science and Veterinary Medicine
Volume 14 Issue 1 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

Study on Odour Attractants to Catch *Glossina pallidipes* Austen *and Glossina fuscipes fuscipes* Newstead (Diptera: Glossinidae) at Sor Hydroelectric Station, Ethiopia

By Waktole Terfa, Abebe Olani & Firaol Tamiru
Ambo University, Ethiopia

Abstract- An experimental study was conducted to assess effects of odour attractants on catch size of Glossina pallidipes Austen and Glossina fuscipes fuscipes Newsteed at Sor Hydroelectric station around Sor River, West Ethiopia. Various doses of acetone, octenol and cow urine were used as odour attractants with monopyramidal traps. Three 5x5 Latin squares method was used making a total of 15 replicates. Acetone released at dose rate of 150mg/hr and 500mg/hr with 0.5mg/hr octenol and 1000mg/hr cow urine were found to be most effective in increasing catch size of Glossina pallidipes Austen by up to 11.26-12.54 times. Acetone released at dose rate of 2000mg/hr in combination with 0.5mg/hr octenol increased the catch only up to 4.07 times but cow urine alone produced increases in catch size by 2.54 times.

Keywords: *Glossina fuscipes fuscipes* Newstead*, Glossina pallidipes Austen, Odour Attractant, Sor River.*

GJMR-G Classification : *NLMC Code: WC 900*

Study on Odour Attractants to Catch *Glossina pallidipes* Austen *and Glossina fuscipes fuscipes* Newstead (Diptera: Glossinidae) at Sor Hydroelectric Station, Ethiopia

Waktole Terfa [α], Abebe Olani [σ] & Firaol Tamiru [ρ]

Abstract- An experimental study was conducted to assess effects of odour attractants on catch size of *Glossina pallidipes* Austen and *Glossina fuscipes fuscipes* Newsteed at Sor Hydroelectric station around Sor River, West Ethiopia. Various doses of acetone, octenol and cow urine were used as odour attractants with monopyramidal traps. Three 5x5 Latin squares method was used making a total of 15 replicates. Acetone released at dose rate of 150mg/hr and 500mg/hr with 0.5mg/hr octenol and 1000mg/hr cow urine were found to be most effective in increasing catch size of *Glossina pallidipes* Austen by up to 11.26-12.54 times. Acetone released at dose rate of 2000mg/hr in combination with 0.5mg/hr octenol increased the catch only up to 4.07 times but cow urine alone produced increases in catch size by 2.54 times. In the trial performed for *Glossina fuscipes fuscipes* Newstead, 0.5mg/hr octenol, 500mg/hr acetone and 1000mg/hr cow urine were used alone and in combination, the catch number of samples from baited and unbaited (control) traps differed slightly. There were no significant repellent or attraction effect as the efficiencies were at roughly the no odour level. In conclusion, cow urine (1000mg/hr) with octenol (0.5mg/hr) and acetone (150 and 500mg/hr) was considered to be a potentially useful combination of baits for *Glossina pallidipes* Austen control and sampling. However, further study should be conducted on behavior and baites used to attract *Glossina fuscipes fuscipes* Newstead in the study area.

Keywords: Glossina fuscipes fuscipes Newstead, *Glossina pallidipes* Austen, *Odour Attractant, Sor River.*

I. Introduction

Trypanosomosis, a disease caused by protozoan parasites of the genus *Trypanosoma*, is still the main constraint to livestock production in Africa, preventing full use of land to feed the rapidly increasing human population (Leak, 1999). The disease is transmitted cyclically by tsetse flies that infest 37 African countries and mechanically by biting flies (Uilenberg, 1998). It has a devastating effect on livestock and man (IAEA, 2003) and can be controlled by drugs or by breaking the transmission cycle, which requires control of the vector tsetse flies. One of the important developments in tsetse control is identification and synthesis of odour attractants for some tsetse species, which greatly increases the efficacy of traps and targets (Leak, 1999).

Tsetse flies use the odours of their vertebrate hosts as cues in host location (Vale, 1974a; FAO, 1992). Some of the active components of breath, urine and skin secretion of hosts have been isolated for use at odour-baited targets and traps used to control and monitor tsetse populations (Dransfield *et al.*, 1986; Vale *et al.*, 1986; Leak, 1999). Acetone, 1-octen-3-ol (octenol) and carbon dioxide from bovine breath and phenols from urine are potent olfactory attractants for several species of the *morsitans* group of tsetse (Vale and Hall, 1985a; Hassanali *et al.*, 1986; Bursell *et al.*, 1988). However, such advances in catch size of some species the *palpalis* or *fusca* group of tsetse has not been realized as much as needed.

Several effective odours are known to attract *Glossina pallidipes* (G. *pallidipes)* (FAO, 1992) including odours of host animals and their residues, which are highly attractants for *G. pallidipes* Austen (Vale, 1974b; Hargrove and Vale, 1978; Vale and Hall, 1985a; Dransfield *et al.*, 1986). Electroantennogram studies in laboratory showed that both sexes of *Glossina fuscipes fuscipes* (*G. f. fuscipes*) Newstead were stimulated by components of bovine odour such as acetone, octenol, 4-heptanone and 3-nonanone (Den Otter *et al.*, 1988). In contrast, Mwangelwa *et al.* (1990) did not observe any consistent effect on catches of *G. f. fuscipes* in biconical traps baited with acetone, octenol, cow urine, phenols or monitor lizard wash.

The success of odour-baited devices for survey and control of *G. pallidipes* in other countries prompted studies in Ethiopia on the attractiveness of natural and synthetic odours, prior to their application in control operations. Thus, more information is needed on the dose response relationships for such attractants, as well as on their effects on the catch of *G. f. fuscipes*. Although baited traps and targets also offer great potential for control or eradication of tsetse flies (Vale, 1980), baseline data should be generated on odour

Author α ρ: Department of Veterinary Laboratory Technology, College of Agriculture and Veterinary Sciences, Ambo University, P.O.Box 19, Ambo, Ethiopia. e-mail: tfiraol@gmail.com

Author σ: National Tsetse and Trypanosomosis Investigation and Control Center, P.O.Box 232, Bedele, Ethiopia.

attractants like cow urine, acetone and octenol in Ethiopia. Therefore, this study was conducted to assess effects of odour attractants on catch size of *G. pallidipes* Austen and *G. f. fuscipes* Newstead using combinations of acetone, octenol and cow urine or alone at different dispense rate at Sor Hydrostation.

II. Materials and Methods

a) Study area

The study was performed in August-September, 2004 in Baro Akobo river system at Sor River around Sor hydroelectric station at position of 08°.23.06"N-08°.24.03"N, 035°.26.05"E-035°.27.02"E and altitude of 1294-1657m. The area is located at about 630 Km southwest of Addis Ababa, capital of Ethiopia, where *G. pallidipes* and *G .f. fuscipes* are abundant. The valley vegetation consists of very dense riverine and evergreen forests. Wild lives are abundant in the area and includes buffaloes, bushbuck, warthog, colobus monkey, baboon, python, etc.

b) Study protocol

Five sites, termed as A, B, C, D and E, were located independently for both species in the forest and near Sor River at about 200m distance interval. All sites were provided with new monopyramidal traps of the same type and size which operate throughout the experiment period. Acetone, octenol and cow urine were used as odour attractants at different dispense rate. The natural odour source, cow urine, was obtained from local zebu cattle. After collection, the cow urine was stored at normal room temperature in stopper bottles up to use for 7 days.

Dose rates were measured by recording the decrease in volume of the attractant over the duration of the experiments and converting to milligrams per hour according to FAO (1992). Acetone was dispensed at different dose rates (150-2000mg/hr) by varying the aperture size of the container. The universal glass bottles were drilled in the lid with single holes 0.2 cm, 0.6 cm and 1.8 cm in diameter to release 150mg/hr, 500mg/hr and 2000mg/hr acetone, respectively at 32°C. Octenol was dispensed at 0.5mg/hr from streptomycin glass bottles, containing 2g octenol and sealed with a rubber septum. Octenol containers were positioned horizontally on their sides or inverted always to keep the octenol in contact with the inner surface of the septum and the octenol diffused out through the septum. The cow urine dispensed by the plastic container of 1 litter volume with 4x4 cm cut on its side to give urine release rate of 1000mg/hr. The dispensers were similar and positioned just beneath the trap. The underneath of trap poles were greased to prevent entrance of ants that may eat flies.

c) Study design

A 5x5 Latin square design (Table 1) replicated three times from 7:00 am to 7:00 am (for 24 hrs) for 15 adjacent days was undertaken each for study of *G. pallidipes* as well as *G. f. fuscipes*. The term 'replicate' denotes the operation of one treatment at one site for one day. Thus, groups of five adjacent days were regarded as different replicates. Blocks and treatments were allotted randomly to days within these blocks.

Table 1 : 5x5 Latin square design

Latin Square	Day	Site				
		A	B	C	D	E
First	1	V	II	III	IV	I
	2	III	I	IV	II	V
	3	II	IV	I	V	III
	4	I	V	II	III	IV
	5	IV	III	V	I	II
Second	1	II	IV	III	V	I
	2	I	V	II	III	IV
	3	IV	I	V	II	III
	4	III	II	IV	I	V
	5	V	III	I	IV	II
Third	1	V	III	II	IV	I
	2	IV	II	III	I	V
	3	I	IV	V	III	II
	4	II	I	IV	V	III
	5	III	V	I	II	IV

Treatment keys: For G. pallidipes: I = trap alone, II = trap + 1000mg/hr cow urine, III = trap + 1000mg/hr cow urine +0.5mg/hr octenol + 150mg/hr acetone, IV = trap + 1000mg/hr cow urine + 0.5mg/hr octenol + 500mg/hr acetone, V = trap + 0.5mg/hr octenol + 2000mg/hr acetone.
For: G. f. fuscipes: I = trap alone, II = trap + 0.5mg/hr octenol, III = trap + 500mg/hr acetone, IV = trap + 1000mg/hr cow urine, V = trap + 1000mg/hr cow urine + 0.5mg/hr octenol + 500mg/hr acetone.

In the experiment for *G. pallidipes,* comparison of unbaited monopyramidal traps versus traps baited with 1000mg/hr cow urine; 1000mg/hr cow urine + 0.5mg/hr octenol + 150mg/hr acetone; 1000mg/hr cow urine + 0.5mg/hr octenol + 500mg/hr acetone; and 0.5mg/hr octenol + 2000mg/hr acetone were used. For *G. f. fuscipes* comparison of unbaited monopyramidal traps versus traps baited with 0.5mg/hr octenol; 500mg/hr acetone; 1000mg/hr cow urine separately, and combinations of 1000mg/hr cow urine + 0.5mg/hr octenol + 500mg/hr acetone were used. To compare the efficacies of various treatments, each treatment was incorporated into a series of randomized Latin square of treatments by sites and by days.

d) Data analysis

The catches in each replicate were transformed to log n+1 and subjected to analysis of variance to determine the probability associated with differences between mean catches. The effects of various odours on the catch of trap were compared with a control treatment consisting of unbaited traps. The detransformed mean catch with a test odour is expressed as a proportion of the detransformed mean control (no odour) catch and is termed the catch index; indices greater than unity indicate attraction and indices less than the unity indicate repellent. Presence of statistical significance difference was determined at $p < 0.05$. The critical F ratio is looked up in statistical table.

III. Results

a) Glossina pallidipes Austen

The treatment factor was found as a significant source of variation ($F=29.36$; critical value=2.52; $p<0.05$). Analysis of variance result of *G. pallidipes* at different rates of acetone together with fixed cow urine and octenol doses is shown in Table 2.

Table 2 : ANOVA of *G. pallidipes*

Source of variation	df	SS	MS	F ratio
Replicates	2	0.5257	0.2629	
Days within replicates	12	3.9709	0.3309	
Treatments	4	9.6883	2.4221	29.3588
Sites	4	1.48	0.37	4.4848
Residuals	52	4.2885	0.0825	
Total	74			

The traps baited with different odour attractants have shown better attraction indices than unbaited traps. The treatment with 1000 mg/hr cow urine + 0.5 mg/hr octenol + 500 mg/hr acetone increased the catch highly by up to 12.54 times, and similarly treatment of trap with 1000mg/hr cow urine + 0.5mg/hr octenol +150 mg/hr acetone increased the catch by 11.26 times. Trap baited with highest release rate of acetone (2000mg/hr) + octenol (0.5mg/hr), and 1000mg/hr cow urine alone increased the catch by 4.07 and 2.64 times, respectively (Table 3).

Table 3 : The means, detransformed means and indices of each treatment increase in relation to T-I treatment (control) for *G. pallidipes* Austen

Glossina pallidipes treatment type	Mean (x)	Detransformed mean(G)	Index
T-I	0.5137	2.2636	1
T-II	0.8441	5.9839	2.6435
T-III	1.4231	25.4911	11.2613
T-IV	1.4683	28.3968	12.545
T-V	1.0096	9.2235	4.0747

b) Glossina fuscipes fuscipes Newstead

The treatment factor was considered as insignificant source of variation ($F=0.6375$; critical value=2.52, $p>0.05$) while site was considered as source of variation ($F=26.6982$; critical value=2.52, $p<0.05$). The results of the experiment comparing trap baited with 0.5 mg/hr octenol, 500 mg/hr acetone, and 1000mg/hr cow urine separately and their combination to catch *G. fuscipes fuscipes* are given in Table 4.

Table 4 : ANOVA of *G. f. fuscipes* Newstead

Source of variation	df	SS	MS	F ratio
Replicates	2	0.0627	0.0314	
Days within replicates	12	1.4722	0.1227	
Treatments	4	0.1426	0.0357	0.6375
Sites	4	5.9803	1.4951	26.6982
Residuals	52	2.9137	0.056	
Total	74			

Since treatment factor was found statistically insignificant, calculating further for index of attraction is not necessary to identify better odour attractant. However, to check the suspicion of their repellent effects was further calculated for indices (Table 5) and found non-repellent roughly.

Table 5 : The means, detransformed means and indices of each treatment increase in relation to T-I treatment (control) for *G. f. fuscipes* Newstead

G. f. fuscipes treatment type	Mean (x)	Detransformed mean (G)	Index
T-I	0.8924	6.8055	1
T-II	0.893	6.8163	1.0016
T-III	0.9655	8.2363	1.2102
T-IV	0.8278	5.7267	0.8415
T-V	0.8925	6.8073	1.0003

IV. Discussion

The efficiency of the traps to catch *G. pallidipes* was high in presence of odour attractants and low in absence of any odour. However, the efficiency was roughly low in the presence of odour for *G. f. fuscipes*. This agrees with the compiled reports of FAO (1992) from many African countries.

a) Glossina Pallidipes Austen

Monopyramidal trap was baited with combination of cow urine (1000mg/hr) + octenol (0.5 mg/hr) + acetone (150 mg/hr) could be the preferred combination of odour attractant in the study even though traps baited with cow urine (1000mg/hr) + octenol at 0.5 mg/hr + acetone (500 mg/hr) performed better. This is due to the expensive cost of acetone at high release rate (FAO, 1992). However, in some small operations like ecological researches the later could be utilized.

In the current study, utilization of baited traps with cow urine alone and different combinations of cow urine, octenol and acetone increased the indices (2.64-12.54 times) of the odours' ability to attract *G. pallidipes*. This agrees with work of Dransfield *et al*. (1986) in Ngurman, Kenya, in which acetone with cow urine produced increases of catch 9-25 times using biconical traps. However, the present result disagrees with the result obtained by baiting F3 traps with acetone at 5-50,000 mg/hr release rate or octenol and cow urine, in which indices increased only up to 1.67 in Somalia (Torr *et al*, 1989). The difference may due to variation in the combination of the odour attractants, release rate and geographical location (FAO, 1992).

The result of the current study indicated increment of index up to 4.07 when acetone (2000 mg/hr) and octenol (0.5 mg/hr) were used together. There is a report of slight increase in the effects of octenol and acetone even though it was statistically not significant in Kenya (Baylis and Nambiro, 1993). However, acetone and octenol dispensed either alone or together did not significantly increase the catch of a trap in Somalia (Vale and Hall, 1985b). According to FAO (1992), using acetone with octenol can double the catch when compared with octenol used alone.

Traps baited with cow urine (1000mg/hr) alone increased catch index up to 2.64 times when compared with unbaited traps in this study. This is slightly in line of agreement with work of Vale and Hall (1985b) in which a mixture of 3-n-propylphenol and 4-methylphenol increased the catch index by 1.5-2 times. According to FAO (1992), 4-methylphenol and 3-n-propylphenol are the most active components in the urine and bovid urine can give substantial increases in catch (2-5) if dispensed at about 1000mg/hr. If a much higher rate of urine is used, it becomes repellent.

Traps baited with 1000mg/hr cow urine + 0.5mg/hr octenol + 150mg/hr acetone and 1000mg/hr cow urine + 0.5mg/hr octenol + 500mg/hr acetone increased catch index to 11.26 and 12.54 times, respectively. The current catch index result is greater than results (catch index 4-6 baited traps over unbaited traps) obtained from a combination of acetone (500mg/hr), octenol (0.8 or 1.5mg/hr), mixture of 4-methylphenol and 3-n-propylphenol (0.8mg/hr) at Galana Ranch, south-eastern Kenya (Baylis and Nambiro, 1993). In addition, the combination of the odours of current study showed much greater catch index than combination of 3-methylphenol, acetone and octenol, which increased the catch 1.6 times in Zimbabwe using F3 traps (Hall *et al*., 1990). However, the current result is less than a combination of acetone,

octenol, 4-methylphenol and 3-prophylphenol that increased catching up to 20 times in Zimbabwe (Vale and Hall, 1985a; Vale *et al.*, 1988). Performance difference of different traps to attract tsetse flies were found minimal ((Baylis and Nambiro, 1993) and this rules out effects of different traps. Therefore, the difference might be due to difference in geographical location and release rate.

b) Glossina fuscipes fuscipes Newstead

Various ketones, octenol, urine and phenols have been tested but results have been inconsistent (FAO, 1992). There was no statistically significant difference in attractiveness of cow urine to *G. f. fuscipes* in the current study. However, there was a significant increase catch of blue-black polyethylene bipyramid traps using local zebu urine (x 1.4) in three of the four trails with the greatest effect (x 4.2) obtained for male *G. f. fuscipes* when the densities of flies were low (less than five male per trap per day) in Central African Republic. The difference between these works may be related to particular environment of the trails (Gouteux *et al.*, 1995).

Odour attractants used alone or in combination in the current study has not significantly increased the catch of *G. f. fuscipes*. According to FAO (1992), the search for odour attractants for this species has so far been unsuccessful, with the exception of carbon dioxide. This is due to the fact that the riverine tsetse species of palpalis-group respond poorly to the odour baits developed for savannah species. The attractants used for the savannah tsetse are hardly or not attractive to palpalis species and sometimes even repel them (Mwangelwa *et al.*, 1995; Späth, 1995). So a full understanding of the types of odour attractants and interplay of responses of *G. f. fuscipes* to different chemicals and suggestion of effective odour bait has to be worked out in the future.

V. Conclusion and Recommendations

In conclusion, different combinations of odour attractants were found to attract *G. pallidipes*. To run some small operations such as ecological research for *G. pallidipes*, traps are required to provide large samples with small cost and convenience. In these circumstances, an appropriate odour would be combination of medium doses of 500mg/hr acetone + 0.5 mg/hr octenol + 1000mg/hr cow urine. For works such as routine surveys or control operations over large areas, a less expensive and more convenient combination of low dose of 150 mg/hr acetone + 0.5 mg/hr octenol and 1000mg/hr cow urine would be more suitable. The latter combination can increase catches by several times for costs that are much less than the equally effective alternative of operating higher doses of odour or more traps. The search for best odour attractant for *G. f. fuscipes* is unsuccessful in the current study. Thus, further studies should be conducted on the behavior and best odour attractant for this species.

VI. Acknowledgment

The authors would like to thank National Tsetse and Trypanosomiasis Investigation and Control Center for budget and technical support. The encouragement and criticism of Dr. Debebe Argago and Mr. Flint S. was very important for this work.

VII. Contribution of the Authors

WT conceived the idea, participated in all field works, analysis and write up of the manuscript. AO participated in all field works and FT participated in data analysis and write up of the manuscript.

References Références Referencias

1. Baylis M, Nambiro CO (1993). The response of *Glossina pallidipes* and *Glossina longipennis* (Diptera: Glossinidae) to odour-baited traps and targets at Galana Ranch, south-eastern Kenya. *Bulletin of Entomological Research* 83: 145-151.
2. Bursell E, Gough AJE, Beavor PS, Cork A, Hall DR, Vale GA (1988). Identification of components of cattle Urine attractive to tsetse flies, Glossina spp. (Diptera: Glossinidae). *Bulletin of Entomological Research* 78: 281-291.
3. Den Otter CJ, Tchicaya T, Van Den Berg MJ (1988). Olfactory sensitivity of five species of tsetse (*Glossina* spp.) to 1-octen-3-ol, 4-heptanone, 3-nonanone and acetone. *Insect Science and its Application* 9: 213–218.
4. Dransfield RD, Brightwell R, Chaudhury MF, Tarimo SAR (1986). The use of odour attractants for sampling *Glossina pallidipes Austen* (Diptera:Glossinidae) at Nguruman , Kenya. *Bull.ent.Res.*76: 607-619.
5. FAO (1992). Use of attractive devices for tsetse survey and contol training manual for tsetse control personnel. Vol. 4: 13-112.
6. Gouteux JP, Blanc F, Cuisance D, D'Amico F, Guinza AK (1995): trials of olfactory attractants to enhance trap catches of *Glossina fuscipes fuscipes* (Diptera: Glossinidae) in the Central Republic of Africa. Vet Res 26, 335-340.
7. Hall DR, Gough AJE, Adams PH, Beevor PS, Cork A, Green CH, Smith JL, Taylor JHL, Warner ML (1990). Identification of host odour attractants for tsetse flies Final Report 1986-1990, Natural Resources Institute, Chatham, Kent.
8. Hargrove JW, Vale GA (1978). The effect of host odour concentration on catches of tsetse flies (Glossinidae) and other Diptera in the field. *Bulletin of Entomological Research* 68: 607-612.
9. Hassanali A, McDowell PG, Owaga MLA, Saini RK (1986). Identification of tsetse attractants from

excretory products of a wild host animal, *Syncerus caffer*. *Insect Science and its Application* 7:5-9.
10. IAEA (2003). Improved attractants for enhancing tsetse fly suppression: Final report of a co-ordinated research project, 1996–2002. Vienna, Austria, pp. 2.
11. Leak SGA (1999). Tsetse Biology and Ecology: their role in the Epidemiology and Control of trypanosomosis. CABI publishing, New York, pp. 2-168.
12. Mwangelwa MI, Dransfield RD, Otieno LH (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: 315–322.
13. Mwangelwa MI, Dransfield RD, Otieno LH Mbata KJ (1995). The responses of *Glossina fuscipes fuscipes* Newstead to odour attractants and traps. *Journal of African Zoology* 109: 23–30.
14. Späth J (1995). Olfactory attractants for West African tsetse flies, *Glossina* spp. (Diptera: Glossinidae). *Tropical Medicine and Parasitology* 46: 253–257.
15. Torr SJ, Parker AG, Leigh-Browne G (1989). The responses of *Glossina pallidipes* Austen (Diptera: Glossinidae) to odour-baited traps and targets in Somalia. *Bulletin of Entomological Research* 79: 99-108.
16. Uilenberg G (1998). A field guide for the diagnosis, treatment and prevention of African animal trypanosomosis. 2nd ed. FAO, Rome, pp. 1-14.
17. Vale GA, Hall DR, Gough AJE (1988). The olfactory responses of tsetse flies, Glossina species (Diptera: Glossinidae), to phenols and urines in the field. *Bulletin of Entomological Research* 78: 293-300.
18. Vale GA, Hall DR (1985a).The use of 1-octen-3-ol, acetone and carbon dioxide in the attraction of tsetse flies, Glossina spp. (Diptera: Glossinidae). *Bulletin of Entomological Research* 75: 219-231.
19. Vale GA, Hall DR (1985b).The role of 1-octen-3-ol, acetone and carbon dioxide in the attraction of tsetse flies, Glossina spp.(Diptera:Glossinidae). *Bulletin of Entomological Research* 75: 209-217.
20. Vale GA (1974a). New field methods for studying the responses of tsetse flies (Diptera: Glossinidae) to hosts. *Bulletin of Entomological Research* 64:199-208.
21. Vale GA (1974b). The responses of tsetse flies (Diptera: Glossinidae) to mobile and stationary hosts. *Bulletin of Entomological Research* 64: 545-588.
22. Vale GA (1980). Field studies of the responses of tsetse flies (Glossinidae) and other Diptera to carbon dioxide, acetone and other chemicals. *Bulletin of Entomological Research* 70: 563-570.
23. Vale GA, Flint S, Hall DR (1986). The field responses of tsetse flies, *Glossina* spp. (Diptera: Glossinidae), to odours of host residues. *Bulletin of Entomological Research* 76: 685–693.