THE RESPONSE OF *GLOSSINA PALLIDIPES* (DIPTERA: GLOSSINIDAE) TOWARDS DIFFERENT TRAP DESIGNS AND ODOUR BAITS AT NECHISAR NATIONAL PARK, SOUTHERN ETHIOPIA

A THESIS PRESENTED TO THE SCHOOL OF GRADUATE STUDIES, ADDIS ABABA UNIVERSITY, IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE IN BIOLOGY.

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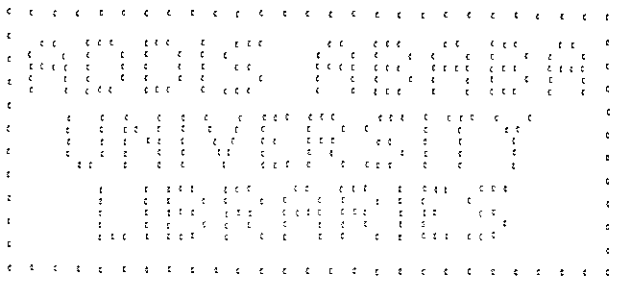

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Abstract

Investigations were carried out in the Nechisar National Park, southern Ethiopia, to determine the preferences of *Glossina pallidipes* (Diptera: Glossinidae) towards different trap types and odour baits, and to standardize the best bait system for catching this fly. Epsilon, F3 and NG2G traps were evaluated in different vegetation types. In experiment two and experiment three, acetone (450mg/h), cow urine (858mg/h) and octenol (1.5mg/h) were dispensed (both separately and in blends) near traps from glass bottles, plastic bottles and sachets, respectively. The results of all experiments showed that NG2G trap was more effective in catching *G. pallidipes* than Epsilon and F3 traps. No significance difference was observed between Epsilon and F3 traps. Among odour attractants tested in blends, acetone + cow urine + octenol and acetone + cow urine were highly attractive to *G. pallidipes* than acetone + octenol and cow urine + octenol. The combinations of cow urine and octenol were found to be more attractive than acetone + octenol. The relatively higher catches obtained by using NG2G traps and cow urine suggests that NG2G trap and cow urine are the best baits for community- based tsetse management. NG2G trap offers some advantages over the other traps used because it is less expensive and is easier to deploy. The availability of cow urine in large quantities with no cost to the rural communities will make fly trapping potentially feasible. Higher percentages of female flies were caught than male flies. All unbaited trap types caught a smaller proportion of older flies of both sexes. Epsilon, F3 and NG2G traps baited with acetone, cow urine and octenol caught a smaller proportion of female flies at their older ages and a higher proportion of male flies. NG2G taps

deployed with different combinations of acetone, cow urine and octenol caught a higher proportion of older flies of both sexes. Tabanidae did show a strong response to blends of odour baits, especially to cow urine + octenol. Biting flies of the sub-family Stomoxyinae respond highly to odour baits and their response varies with vegetation type.

1. INTRODUCTION

Tsetse flies (*Glossina spp.*) are the natural vectors of the African trypanosomosis. The disease is endemic and remains a threat to both human and livestock in many rural communities of sub-Saharan Africa (Peter *et al.*, 1996). Jordan (1986); Jahnke *et al.*, (1988) and Winrock International (1992), cited in Hendrickx *et al.*, (1999) indicated that tsetse-transmitted trypanosomosis has been identified as a major constraint to livestock production in the subhumid ecozone of sub-Saharan Africa. Moreover, tsetse infestations are believed to prevent the successful integration of crop and ruminant production. Apart from the disease situation, which develops after an infective tsetse fly bite, it is argued that the mere presence of tsetse creates imbalances in the distribution of susceptible livestock and thus influence the type and number of animals kept, the use of oxen for drought power, manure as crop fertilizer and crop residuals and byproducts as cattle feed (FAO, 1992).

Glossina pallidipes Austen 1903 is considered as the most important vector of animal trypanosomosis. This species occurs in Ethiopia, Somalia, Kenya, Uganda, Tanzania, Rwanda, Zambia, Malawi, Mozambique, Zimbabwe, Zaire (Moloo, 1993) in a range of vegetation types and climatic conditions (Jordan, 1986). The current distribution of *Glossina spp.* in Ethiopia is not clearly demarcated because of recent progress of the species into some areas and disappreance from other areas. However, Ovazza and Rodhian (1972), Fuller (1978, cited in Temesgen Alemu (1994) indicated that *G. pallidipes* is common along the Omo River, along the Southern edge of the plateau from Lake Chamo in the Rift Valley to Sobat and Blue Nile drainage basins, Sangan River, across the lowlands

between the Omo River, Sobat drainages and Gojeb River. *G. pallidipes* is also reported to be near Gambella at the head of Gilo River and in the center of Omo River Valley.

Control of tsetse flies and hence of African trypanosomosis can be achieved by a variety of methods including the use of traps and targets (Vale *et al.*, 1988). Dransfield *et al.*, (1990, cited in Brightwell *et al.*, 1992) found that odour-baited traps reduced about 99% and 90% of the populations of *G. pallidipes* at Nuguraman, Kenya, in the dry and rainy seasons, respectively. However, during the rain, reinvasion primarily by females, occurred. An increasingly important method of controlling human and animal trypanosomosis uses traps or insecticides impregnated targets baited with synthetic attractants to lure and kill tsetse flies (Green, 1994). The success of controlling tsetse flies using different trap types and odour attractants depends partly on the ability of the bait to attract very large number of flies for extended periods (Hargrove and Vale, 1978).

So far, visual and olfactory attractants have been widely used for tsetse control (Chorley, 1948; Owaga, 1984). Major advances have been made on the discovery of effective devices, which can be used to increase the number of flies either entering the trap or aligning on the target so that few are required per unit area (Vale, 1991). Odour-baited traps have valuable aids to sampling the population of tsetse, particularly *G. pallidipes* (Dransfield *et al.*, 1990) and offer promises as means of tsetse control and eradication (Vale, 1980). Therefore, in the present study field experiments have been conducted to determine the performances of unbaited and baited Epsilon, F3 and NG2G traps. First, studies were conducted on unbaited traps. Secondly, investigations were made on the same trap types used in experiment one but baited with acetone, cow urine and octenol. Thirdly,

based on the results of experiment one and two similar investigations were conducted on the effective trap baited with different combinations of different odour baits.

In all investigations comparisons were made on:

(I) The total number of *G. pallidipes* caught by

(a) each trap type for experiment one and two, and

(b) each odour combination deployed with effective trap in experiment three

(II) Sex ratio (male to female *G. pallidipes*)

(III) Age composition, and

(IV) The total number of Tabanidae and Stomoxinae caught in all experiments

OBJECTIVES OF THE STUDY

General objective:

- To assess the catch size of different trap designs and odour baits for sampling *G. pallidipes*.

Specific objectives:

- To investigate the performance of unbaited Epsilon, F3 and NG2G traps in catching tsetse fly
- To investigate the best performance of the same traps baited with acetone, cow urine and octenol, and

- To assess the performances of selected trap in experiment one and two baited with different combinations of different odour baits (Acetone + Cow urine + Octenol, Acetone + Cow urine, Octenol + Cow urine, and Acetone + Octenol).

2. LITERATUE REVIEW

2.1. Distribution and abundance of tsetse flies (*Glossina*)

Glossinid flies are confined to Africa (Glasgow, 1963; Laird, 1977; Moloo, 1993). They are endemic to Afrotropical Region where they potentially occupy an area of 10 million km^2 (Corfield, 1993). There are also evidences indicating that tsetse flies once existed in Colorado, North America (Oldroy, 1964; Kettle, 1984). There is also an old confirmed record for *Glossina tachinoides* from South Yemen, and, recently, *G. morsitans submorsitans* and *G. fuscipes fuscipes* have been detected in Saudi Arabia near the border with North Yemen (Nagel, 1995; Leak, 1999).

Ford (1962, cited in Leak 1999) indicated that the Southern limits of *Glossina* distribution in Africa lie North of a line drawn from Benguela in Angola, to Durban in South Africa. He also noted that the northern limit lies from Dakar in Senegal across to Ethiopia and Mogadishu in Somalia on the East Coast. Within these broad limits, tsetse flies are unevenly distributed as their occurrence is affected by a number of factors. A comparative research conducted on the abundance (density) of *G. pallidipes* in forest, bushes, thickets, and fallow plots showed that the density of *G. pallidipes* was relatively higher in the fallow land, and lowest in the forest (Odino and Amutalla, 1986).

In Ethiopia, different species of tsetse flies occupy a vast area of arable land in the low lands. The total area infested by tsetse flies in 1976 and 1988 was 98,000 km^2 and 120,000 km^2, respectively (Langridge, 1976; FLDP, 1989). The distribution of tsetse flies is still in advance in some areas including the upper latitudinal limits. The general distribution of tsetse flies is

determined by climate, altitude, vegetation type and the availability of suitable host (Leak, 1999).

2.2. Factors affecting the distribution of tsetse flies

2.2.1. Climate

Temperature and moisture are the most important climatic factors that determine the distribution of *Glossina*. Normal development of the fly requires a temperature range between 16 ° C and 38 ° C. Higher or lower temperatures of this range can either be tolerated for shorter periods of time or the adult tsetse flies actively retreat to microclimatically favorable habitat (Nagel, 1995). Bursell (1960c, cited in Glasgow, 1963) stated that a slight variation from the given temperature ranges may have lethal effect both on adult and a pupal stage as the fat reserve is exhausted. Thus, long period of low temperatures at the southern end of tsetse flies distribution (southern Mozambique, Zimbabwe, Botswana, southern Angola and southern Zambia) and very high temperatures combined with dryness and lack of cover in the north west Africa, in most part of the Sudan, part of Kenya, Ethiopia and Somalia make conditions unsuitable for tsetse (FAO, 1978). Temperature is an important factor for both the survival of adult flies and pupal development (Nagel, 1995). Tsetse pupae also require a humid (but not dump) soil to develop favorably. An experiment conducted on starved teneral flies, kept at a relative humidity of 80 percent and 0 percent indicated that the flies died of after exhausting its reserved fat and desiccation, respectively. Although ambient humidity governs water loss, non-teneral flies could control the rate by controlling the spiracles to some extent (Glasgow, 1963). In general, atmospheric humidity allows tsetse flies to disperse into more open land (*G. morsitans* for instance), or allows the flies to live away from free water (*G.*

palpalis and *G. tachinoides*) in which the flies used to live during the dry season (FAO, 1982).

2.2.2. Altitude

Altitude influences tsetse distribution through its effect on climate, particularly, on temperature. Getachew Tikubet (1983) in his study, performed using the screen/ hand net and vehicle patrol method, in Finchaa River Valley, western Ethiopia, showed that the number of flies captured decreased as altitude increases. In the same area, 1,600 m was considered to have been the upper altitudinal limit to tsetse distribution (Langridge, 1976). Subsequently, however, *G. pallidipes* was found at altitudes up to 2, 2000 m (Getachew Tikubet and Teferi Gemetchu, 1984).

2.2.3. Vegetation

Vegetation of different types such as trees, bushes, or thickets provide suitable climatic conditions for the tsetse (FAO, 1982). It is also an important habitat for the host of tsetse flies so that the distribution of the known species and subspecies of *Glossinidae* is restricted to particular vegetation types. Some of them live in a wider range of environment, and have a wide distribution, while others live in a narrower range of conditions, and have a more restricted range of distribution (Laird, 1977). The morsitans groups inhabit more or less open land, woodland, thorn bush and savanna. The palpalis groups on the other hand, live in denser, wetter, heavily forested areas either in the equatorial rainforest proper, or in local patches like the gallery forests following the banks of streams in arid areas (Olroyd, 1964). Except *G. brevipalpis* and *G. longipennis*, the fusca groups are associated with

equatorial rainforest, and most of the species occur in Central and West Africa (Nagel, 1995).

2.2.4. Host range

Both sexes of adult *Glossina spp.* are haematophagous. After analyzing a large number of blood meals found in the digestive tract of captured flies of different species, researchers identified the main host groups (Laird, 1977; Leak, 1999). Feeding habits of a particular species could vary depending on its geographical range or the particular season of the year. Principally, tsetse flies feed on the blood of mammals, reptiles, and very rarely, on birds. However, the blood of birds and reptiles serves as food resource only in a few species (Nagel, 1995).

Odulaja and Nokoe (1992) reported that the distributions of flies vary widely in density and are usually highly clustered, closely related to the presence of preferred host (mainly wild animals). High densities of wild animals often occur in game reserves and other natural areas having low human population densities.

2.3. Morphology and classification

Tsetse flies body has some shade of brown or gray brown, and sometimes it has a slight pink or sandy- red tinge. Several species are very dark. The body usually has darker and lighter patches, making the insect difficult to see when it is settled on bark, rock or soil (FAO, 1982). There are medium to large flies, 6 to 14 mm long, excluding the proboscis. They have forwardly directed proboscis with ensheathing palpi, cyclorrahaphan type antennae and dioptic eyes (Kettle, 1984). The wings are folded one over the other like the

blades of a pair of scissors, with their tips projecting beyond the end of the abdomen. The discal cells of the wing veins are hatchet shaped and lie between longitudinal wing veins IV and V, and the presence of secondary branches on the hairs of the antennal arista distinguish *Glossina spp.* from other diptera (Laird, 1977). The two sexes are only a little dissimilar in appearance and the females are slightly larger while males are easily recognized by the presence of postero ventrally hypopygium on the abdomen (Glasgow, 1963).

Tsetse flies are classified in one genus, *Glossina* of the family *Glossinidae*, Order Diptera. There are 31 species and subspecies, including *G. frezili* (the most recently identified species) (Leak, 1999). The genus Glossina is divided into the fusca-, morsitans-, and palpalis- groups based on morphological differences in the structure of the genitalia (FAO, 1978). Itard and Jordan (1986), as cited in Nagel (1995), subdivided tsetse flies into three different sub- genera; i.e. sub-genus Austenia, Glossina, and Nemorhina, formerly referred to as the fusca group, morsitans group, and fusca group, respectively, based on their distribution and ecology.

2.4. Biology and activity pattern

Tsetse flies are viviparous, the female producing full-grown larvae. With free access to the host, the female tsetse will have a fully developed egg ready for ovulation seven to ten days after emergence (Kettle, 1984). Mating may take place before or while taking the first blood meal close to or on the host animals. Each female tsetse fly mates once, but some may mate more than once and stored in a spermathecae (Nagel, 1995). The egg that is

fertilized by the sperm in the uterus lasts for about four days. The larva is hatched and the secretion of uterine gland nourishes it. The larva passes through three developmental stages (1st instar, 2nd instar, and 3 rd instar) in the uterus and the third stage larva is deposited on shady sites to be protected from dessication. Immediately after oviposition, the larva is capable of slow movements, and can burrow into the soil (Glasgow, 1963; FAO, 1978). Free living larva that is buried under the surface of the soil metamorphoses into barrel-shaped pupae. Pupation occurs within one to five hours of deposition depending on the presence or absence of light and mechanical stimulation of a particular substrate (Kettle, 1984). The time in which the adult emerges from the pupal case varies among *Glossina spp.* and depends on environmental conditions in different localities. At the time of occlusion the adult fly is soft and the wings are crumbled so that the development of wings and the hardening of exoskeleton follows (Laird, 1977; FAO, 1978). The reproductive rate of the tsetse fly is extremely low as compared to other insect groups. On the average a female tsetse fly may produce between 8 and 10 larvae, and Glossinid flies have a relatively constant population size compared, for instance with mosquitoes (Nagel, 1995).

Tsetse flies are diurnally active although some species such as *G. longipenies, G. pallidipes*, and *G. brevipalpis* have been observed both flying and attacking at night. When active, the flies usually search for food, the male searches for a mating partner followed by the female search for a larviposition site, and the search for resting places (Laird, 1977). Temperature, humidity, odours, wind direction and wind speed, and colour influence the activities of tsetse fly (Leak 1999). Brady (1972), Turner and Invest (1973), cited in Green 1994) showed that movement is a powerful activating stimulus and tsetse becomes

increasingly responsive with progressive starvation. Some species of *Glossina* change their habitat seasonally. Daily habitat changes have also been observed. During the rainy season they spread all over the savanna, but during the dry season tsetse flies prefer dense stands of the vegetation and the vicinity of water. During the day, they mostly rest on tree trunks, under big branches or in earth-or-tree cavities close to the ground and/ or close to water. During the night, some respond to temperature changes and move to rest on tree canopy (Nagel, 1995). Foraging for blood meals is the most frequently recurrent and probably the most targetable of all activities that render tsetse vulnerable to interception with static trapping devices (Madubuni, 1995).

2.5. Medical and Veterinary Importance

Tsetse flies are probably present in sufficient density to pose a biting problem. They are the principal vectors of African trypanosomosis, which affects man and his domestic animals, and can cause considerable suffering and economic loss (Buxton, 1955; Mullingan, 1970; Jordan, 1986; Green, 1994). Trypanosomosis is a series health problem causing sleeping sickness in man and in cattle nagana. It is the most important livestock disease in Africa (ILRAD, 1990).

Among the species of the morsitans group, *G. pallidipes* and *G. morsitans;* from the palpalis group *G. palpalis, G. fuscipes* and *G. tachinoides* have major economic importance. The palpalis group occurring in the Riverine and lakeside habitats is particularly important as vectors of human trypanosomosis, while animal trypanosomosis is

associated with tsetse flies of the morsitans group. Except *G. brevipalpis* and *G. longipenis,* forest dwelling species of the fusca group have little economic importance (Kettle, 1984).

2.6. Control strategies against trypanosomosis

Tsetse transmitted trypanosomosis has been identified as a major constraint to increase live stock production in the subhumid ecozone of sub-Saharan Africa. Moreover, tsetse infestations are believed to be preventing successful integration of crop and ruminant production (Jordan, 1986). So, the current deficit of food across the continent with increasing population growth is likely to increase unless effective remedial actions can be taken against this problem (FAO, 1994). Thus, different control measures have been directed against either the parasite, or against the vector (tsetse flies), or both.

2.6.1. Control measures directed against the parasite

Sleeping sickness and nagana are caused by different species of *Trypanosoma. Trypanosoma brucei rhodesiense* and *T. b. gambiense are* the causative agents of sleeping sickness and *T. vivax, T. congolense,* and *T. b. brucei* primarily cause nagana. Askew (1971); Borror *et al.,* (1976), Amseler *et al.,* (1993), cited in Gillott (1995) indicated that tsetse flies take the pathogen (trypanosomes) with their blood meal. Thus, the most wide spread type of trypanosomosis control has been the use of trypanocidal drugs administered to domestic livestock. Phenatridines, isometamidium, homidiium, and the aromatic diamidine and diminazene are the currently recommended chemotherapy of animal trypanosomosis. Isometadium and homodium are the only recommended drugs for prophylaxis (Leak, 1999).

Perry (1992, cited in FAO, 1994) reported that chemotherapy (curative measures used against the parasite) has been constrained by reliance on a severely restricted number of compounds which result in the development of resistance by the parasites. The demand for the development of other control measures, rather than trypanocides, is increasing because: (a) - the cost of developing new trypanocides is increasing (b) - those costly trypanocidal drugs have relatively small commercial market (c) -the parasite develops resistance to the available drugs.

The use of trypanotolerant livestock in tsetse infested areas as a means of controlling African trypanosomosis has also been used, and at present trypanotolerant taurine (humpless breeds of cattle) live in sub-humid and humid northern parts of sub-Saharan Africa. The Orma Boran and the Masai zebu breeds in east Africa, breeds of sheep and goats also have innate resistance to trypanosomosis. But livestock owners are not attracted to the smaller trypanotolerant breeds (Hoste, 1987; FAO, 1998).

2.6.2. Control measures directed against the vector

Control of the tsetse has been one of the principal weapons in the fight against trypanosomosis, and a variety of methods have been practiced for more than 80 years (Buxton, 1955; Mulligan 1970; Jordan, 1986).

2.6.2.1. Habitat modification and game eradication

Tsetse can be controlled effectively by removing the vegetation that they depend on for their habitat and by killing wild animals on which they depend for their food. Killing wild animals has never been practiced as a control measure for sleeping sickness. The complete or partial clearance of shrub or woody vegetation was widely practiced in the past as a method for controlling trypanosomosis. Theoretically, habitat modification as a means of tsetse control could long last as compared to other methods, particularly if the altered habitat is maintained in a state unsuitable for tsetse to live long by appropriate land use, such as cultivation (Leak, 1999). The disappearance of *G. m. submorsitans* from much of north Nigeria, where the fly is unable to exist above certain densities of human population, indicates that it is particularly sensitive to habitat changes (Jordan, 1986). Until the 1960's, tsetse control was also attempted by game eradication that led to short-term tsetse elimination. This is because the immigration of wild animals to areas which have been cleared of bigger animals and the survival of other wild animals that had not been recognized as potential hosts give the flies to recover (Nagel, 1995). At present, both game elimination and bush clearing (habitat modification) are not recommended as control measures because they are labour intensive and they are not ecologically or environmentally sound (FAO, 1986).

2.6.2.2. The use of traps and targets

Control of some *Glossina spp.* can be achieved using traps and targets as tsetse flies have low reproductive capacity. The basic principle of trapping is to attract tsetse in large

numbers using either traps or targets, and then to kill them using insecticides or a cage (on traps) from which they can not escape. Little sustainable mortality pressure (4 % of the female population per day), additional to natural mortality, needs to be exerted on a population in order to achieve effective control (FAO, 1992). Traps and targets have also been used to create barriers against reinvasion of treated areas.

The efficiency of traps and targets in tsetse control depends on their shape, size, and colour. Compact shapes (e.g. squares and circles) were more attractive than vertically and horizontally oblongs to *G. pallidipes* and *G. morsitans* (Torr, 1989; Vale, 1991). Vertically oriented biconical trap and its derivatives are highly effective for the species of palpalis group. Royal blue is highly attractive, and strongest landing responses are induced either on dark surfaces or those strongly reflective in the ultraviolet (Jordan, 1986). The discovery of effective odour attractants, especially for morsitans species, and recently for some species of the palpalis and the fusca group increases the efficiency of traps and targets in tsetse control (FAO, 1992). The development of trapping technology of tsetse control has concentrated on improved and cheaper designs of traps and targets. Trap efficiency that determines the proportion of tsetse flies that are killed, has often been the subject of experimentation over the years (Odulaja and Nokoe, 1992).

From the beginning of the 19th century, tsetse traps and targets have been used to reduce the population densities of tsetse flies. Their further development and the use of attractants led to environmentally-sound and effective methods for the control of some tsetse species (Odulaja and Nokoe, 1993; Nagel, 1995). Behavioral resistance to traps and targets may

arise, but seems unlikely since most of the visual and olfactory responses included are used in host detection (Brightwell *et al.*, 1991).

2.6.2.3. Chemical insecticides

At the end of the 1940`s, it was noticed that the number of tsetse flies was reduced when residual acaricides were applied on cattle to control ticks and other ectoparasites (FAO, 1992). The impact of such acaricides and the development of insecticidal chlorinated hydrocarbons led to the use of large-scale insecticide application on tsetse flies. Until recently, this has been the most widely used and applied technique (Nagel, 1995).

Insecticides are applied on trees or parts of trees (such as trunk, leaves, underneath the larger branches or tree holes), which serve as resting sites for tsetse flies (FAO, 1978). Insecticides are also spread on attractants (traps, targets, or cattle as "living targets") (Green, 1994) so that adult tsetse flies either come into direct contact, and take a lethal dose of the active ingredient (Leak, 1999), or insecticides may be repellent to the flies. They may have also a knock down- effect that may lead to mortality.

A research conducted from 1986 to 1993 in the Ghibe Valley, south western Ethiopia, on the effect of synthetic pyrethroid insecticides, cypermethrin (Rs-alpha-cyano-3-phenoxy-benzyl [IRS] cis, trans-3- [2,2dichlorovinyl]-2,2dimethyl cyclopropane carboxylate on population of *G. pallidipes* Austen and *G. morsitans submorsitans* Newsteads, indicated 93% and 83% reduction in the apparent densities of the respective species (Leak *et al.*,

1999). Okiria and Kalunda (1994) also showed the lethal and knock down-effect of delthamethrin on *G. morsitans, G. Pallidipes*, and *G. fuscipes fuscipes*.

By considering the importance of insecticides for tsetse control, a wide range of insecticides have been tested inorder to improve the economic cost /benefit ratio and /or reduce the adverse effects on non-target organisms and the environment (Nagel, 1995). Besides this the vector may also develop resistance against the chemicals.

2.6.2.4. Sterile insect technique (SIT)

Pupae or young adult males are sterilized by irradiating them from a radioactive source or by contact with sterilizing chemicals. Once sterilized the flies are released, copulate with wild females which, consequently, can not produce offsprings so that the population is reduced overtime. In this method a long-term success can only be expected if the sterilized males clearly out number the wild males (approximately at a ratio of 10:1) (FAO, 1986; Nagel, 1995). It is very specific but the effect on tsetse population occurs only after a period opposed to control by instantly killing insecticides (FAO, 1998). The most detailed studies and operations have been carried out in Burkinafaso, Nigeria, Ghana, Mali, Uganda, Zambia and Zanzibar Islands. However, up to know, only feasible for a few *Glossina species* and locally practiced with success as part of an integrated control (Nagel, 1995)

2.6.2.5. Biological Control

Biological control of tsetse flies seems to be feasible only by means of predators, parasites, parasitoids or pathogens, which are either exclusively or at least to a large extent, specialized on tsetse flies (Nagel, 1995).

Among arthropods, the most important predators of tsetse flies are probably ants, asilids (robber flies), wasps, and spiders feeding on adults (FAO, 1982). Larvae and pupae of tsetse flies are also prey of ants and insectivorous insects such as ground beetles (*Carabidae* e.g. Cicindelinae, Carabinae). Adult tsetse flies are also assumed to be the prey of insectivorous bird species (e.g. guinea fowl, francolins). Although tsetse flies have such a number of predators, they do not appear to reduce tsetse population significantly in the long term (Nagel, 1995).

To date no practicable methods have been developed for the control of tsetse flies by parasitoids and pathogens (viruses, fungi, bacteria and protozoans). However, Chrestomutilla (Hymenoptera) and Exhyalanthrax (Diptera: Bombylide) are the most important and best known parasitoid insect of tsetse pupae (FAO, 1982; Nagel, 1995) while nematodes of the family *Mermithidae* are noticeable parasite of adult tsetse flies (Laird, 1977).

2.6.2.6. Integrated control

Combing different control methods against a parasite or the vector is very relevant for the control of trypanosomosis. This is because drug prices, drug and pesticide resistances are all on the increase. The sequential use of insecticidal spraying or insecticide impregnated

targets followed by the sterile male technique, or a combination of chemoprophylaxis against the disease and insecticidal application on the cattle against the vector, for example, may greatly improve the trypanosomosis situation. But, when different control measures are used in combination, the combination should be cost effective as well as all measures should act in a complementary way (FAO, 1986; FAO, 1998).

3. MATERIALS AND METHODS

3.1. Study area

The study was conducted at Nechisar National Park, Southern Ethiopia (Fig.1), about 505 km. far from Addis Ababa. The park covers an area of 514 km^2 and lies between N 6^0 00' latitude and E 37^0 45' longitude. Elevation varies from 1108 to 1650 meters above sea level. It is bound to the east by the Amaro district, to the west the town of Arbaminch, and to the north and to the south by the Lakes Abaya and Chamo, respectively (ABSNNP, 1996). The park was chosen for the study because of its high fly population density, different vegetation types, and a good altitudinal gradient. Moreover, the area is easily accessible and offers an ideal situation to study the ecology and behavior of tsetse flies (Verysen, 1998).

March to May and September to November are two distinctive rainy seasons of the area. The mean annual rainfall is about 900 mm. The minimum and the maximum temperatures of the area range from 11.8°C to 13.3°C and 15.2 to 26.8°C, respectively (ABSNNP, 1996). However, during the study period (September to April) the monthly mean minimum and maximum temperatures range from 13.7°C to 17.5°C and from 28.4°C to 31.2°C, respectively. Data for the monthly mean minimum and maximum temperatures of the area during the study period was obtained from the National Meteorology Agency.

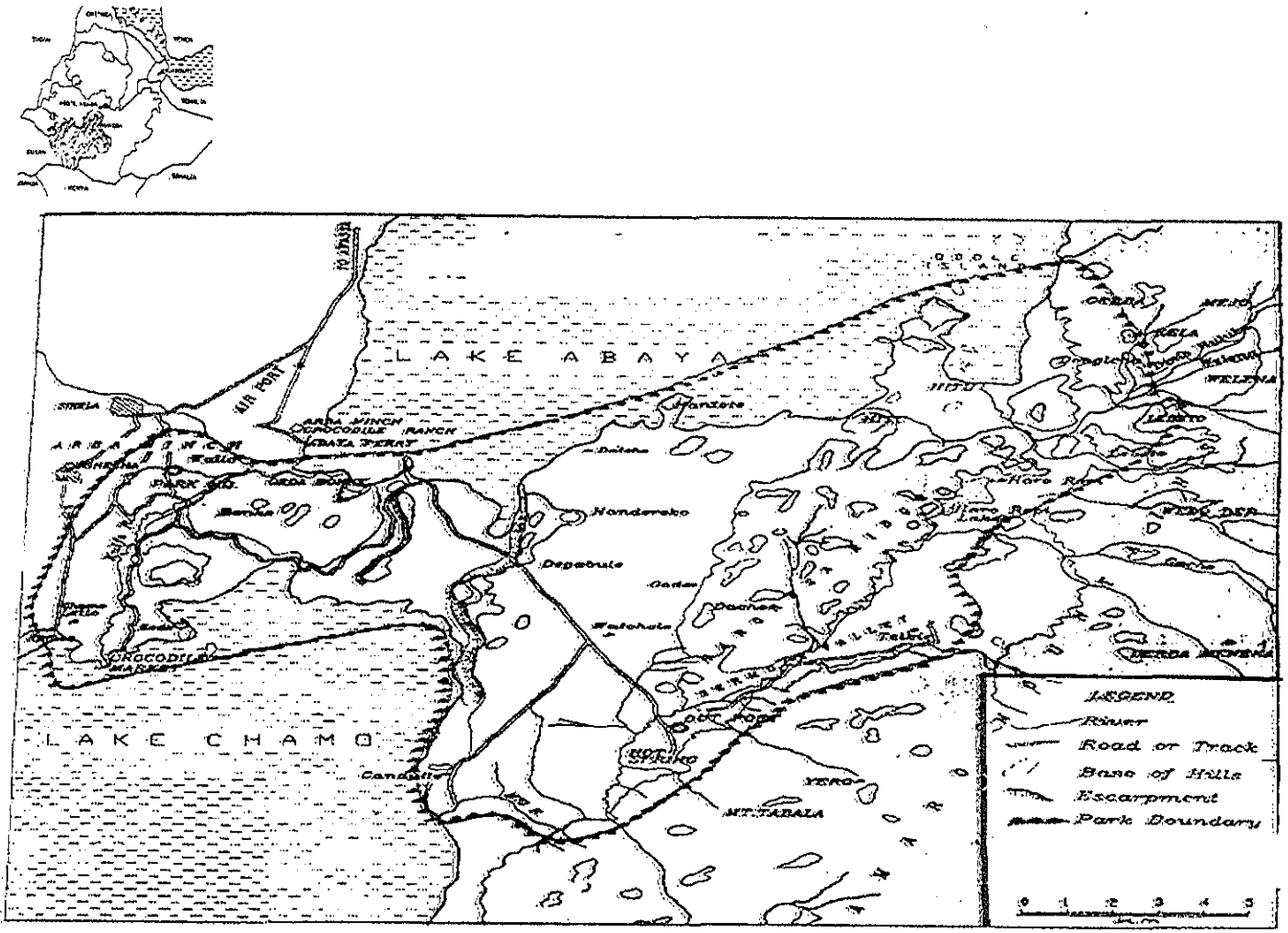


Figure 1. Map of the study area (Source: ABSNNP, 1996)

3.1.1 Vegetation

Savanna land, Bush land, Wood grassland (Plate 1A), Thicket with scattered bushes (Plate 1B), and Riverine (Plate 1C) forest characterize most of the area. Wood grassland is mainly composed of *Scleocarya birra*, *Balanittes* a*egiptics* and *Heteropogon contortus*. *Maerva crassifolia* (*Capparidcea*), *Cissus quadrongularis* are the dominant plant species in Thicket with scattered bush area and the Riverine forest is mainly composed of *Rosaceae*, *Syzygium*, and *Moraceae*.

3.1.2. Wild animals

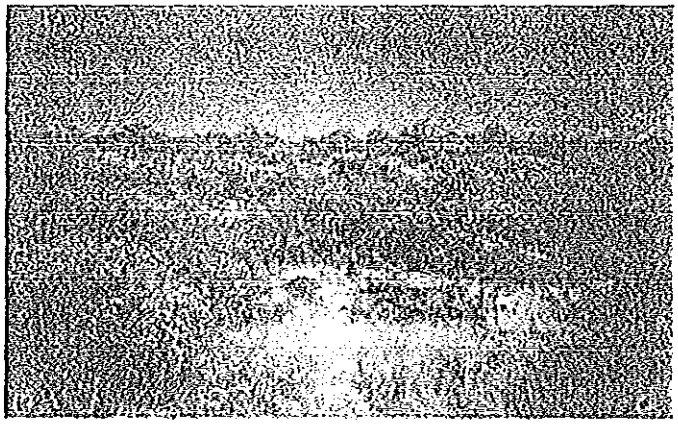
The study area holds varieties of game animals among which Leopard (*Panther paradus*), Greater Kudu (*Tragelaphus strepsiceros*), Grant`s Gazelle (*Gazella granti*), Burchells Zebra (*Equus burchelli),* Warthog (*Phacochoerus africans*) are commonly seen in the park. Lion, Bush Pig, Porcupines, Mangoes, Serval Cat, Olive Baboon, Colobus and Gravets, and many other small diurnal and nocturnal mammals are also available in the park. In Lakes Abaya and Chamo there are Hippos and Nile Crocodiles (ABSNNP, 1996; Urban and Brown, 1968; Hillman, 1993).

3.2. Materials

3.2.1.Traps

The traps used for the study were Epsilon (Plate 2A), F3 (Plate 2B), and NG_2G (Plate 2C) traps. All were locally made based on models of each type. They were made of the same lightweight blue and black cotton clothes and white nylon netting. This is because of their high reflectance that attract tsetse flies (Green, 1994). For Epsilon and F3 traps plastic bottle cages and for NG_2G plastic bag cages were used. Wire strings were tied to a stick

A



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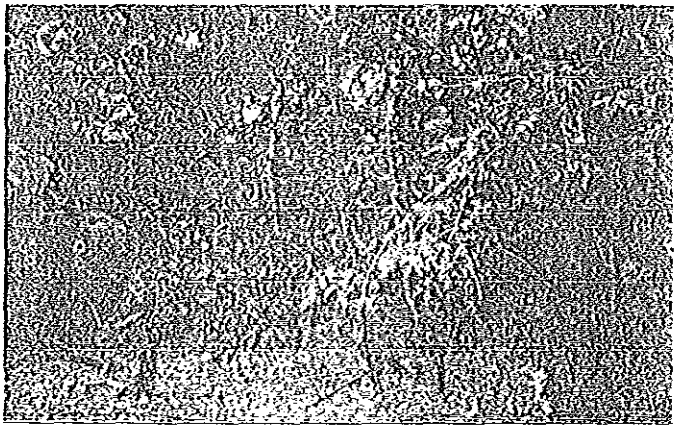
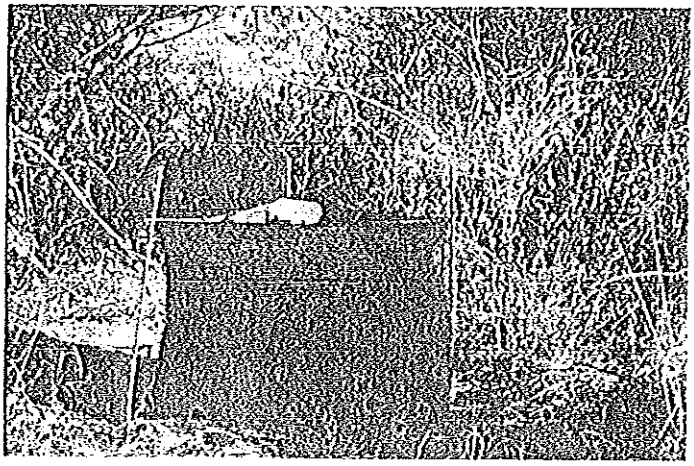
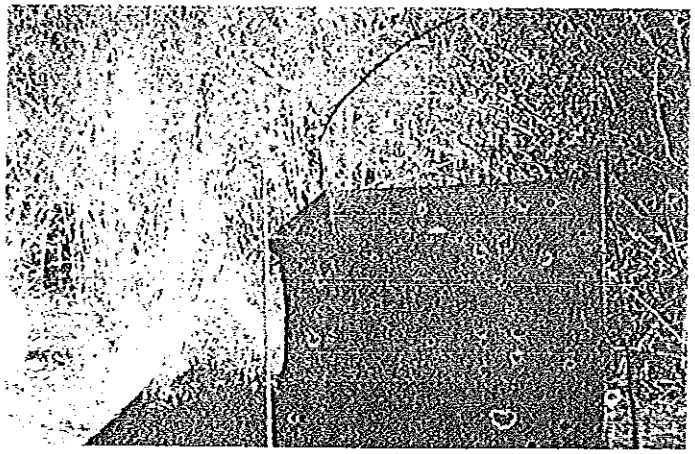


C

Plate 1: Photograph showing different vegetation types of the study area (A) Wood grassland, (B) Reverine forest, (C) Thicket with Scattered bushes



(A)



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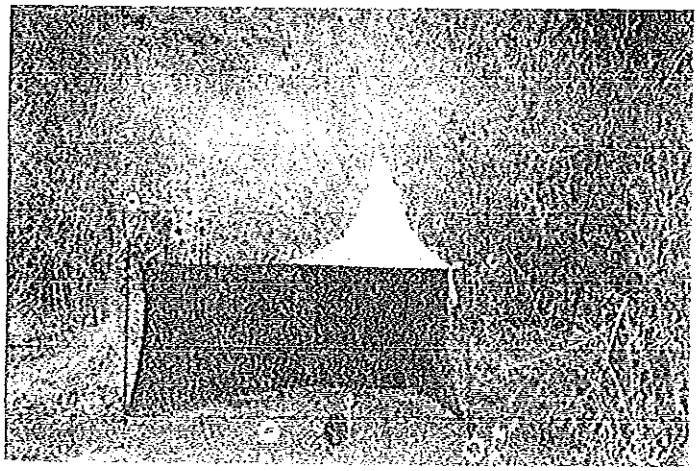

(C)

Plate 2. photographs showing different trap designs. (A) Epsilon, (B) F3 (C) NG2G

inserted into external iron poles to support the cages. A slight modification was made while deploying F3 traps, i.e. traps were supported by four external metal poles (Plate 3B) instead of thirteen metal poles Green and Flint (1986) which are costly. All wires and poles leading to the trap were greased to prevent ants from accessing the collecting cages. NG_2G, Epsilon and F3 traps were selected for the present study based on the results of different researches that were conducted in Kenya, Somalia and Zimbabwe, indicating that these traps are more attractive for *G. pallidipes* than other trap types (FAO, 1992). Different species of tsetse or population of the same species may respond to different baits differently in different habitats so that the experiments were conducted to study the behavior of *G. pallidipes* in a park in Ethiopia.

3.2.2. Odour attractants and dispensers

Three odour baits (cow urine, acetone and 1-octen-3-ol (henceforth termed as octenol) were used. Cow urine was collected from local cattle, and kept for at least three weeks prior to use for bacterial action to take place and increase its phenolic content. Plastic bottles with an aperture cut measuring 2×4 cm in the side near the top and glass medical bottles with a hole of 7 mm diameter on its lid were used to dispense cow urine and acetone, respectively. Flat and rectangular sachets made of 175μm thick polythene sheet with a surface area of 5×4 cm were used for octenol (FAO, 1992).

3.3. Experimental set up

All experiments were performed in Wood grassland (Plate 1A), Riverine forest (Plate 1B), Thicket with scattered bushes (Plate 1C). Flies (*G. pallidipes*) were collected systematically

from nine sample sites of each vegetation type (for experiment one and experiment two), and from twelve sites of each vegetation type (for experiment three) following the method used by Vale (1974). In order to increase the visibility of the traps to flies the ground within 3m radius of each trap site was cleared of vegetation (Vale, 1991). The experimental design used was latin square design because of its supposed ability to minimize day and site effects on the treatment (Vale *et al.*, 1988). Traps were deployed about 200 m apart. For experiment two and three, traps were baited with cow urine, acetone, and octenol, and their combination dispensed at average release rates of 858 mg /hr, 450 mg/hr and 1.5 mg/hr, respectively. All odour sources were placed on the ground 30 cm down wind of the trap (Vale *et al.*, 1988). All release rates were estimated by measuring the weight loss of odour samples kept out doors (Baylis and Nambiro, 1993) from 0730 to 1730 hrs., repeated for five days (for acetone and octenol) and for seven days (for cow urine). Triple beam balance, for cow urine and electronic balance for acetone and octenol were used to estimate weight loss. The experiments were run between 0730 and 1730 hrs. each day when the flies (*G. pallidipes*) were active. Once the flies were collected, they were brought to the laboratory, kept fresh in the ice box, and separated by species using Buxton (1955), FAO (1982), and Murray *et al.* (1985) keys. They were also isolated by sex and age. Flies ages were estimated using wing fray method of Jackson (1946), for male flies, and ovarian aging for female flies by the methods of Saunders (1962). The wings of male flies were placed in a drop of water on a slide and examined through a stereoscopic microscope. The degree of wear and tear on the trailing edge of the wing was then compared with the set of standard charts having 1-6 wing fray categories. In ovarian dissection, after removing the wings and the legs, the female reproductive system was pulled out using Borradaile needle through the

tip of its abdomen. A drop of 0.9% saline solution was, then, added to the reproductive system and the relative development of ovaries, ovarioles and uterus content were examined in order to estimate the number of ovulations. The numbers of ovulations were indicated 0, 1,2,3, 4+.... However, we used 0-3 and 3n+ ovarian age categories since flies in 0-3 categories can be age-estimated with considerable accuracy (FAO, 1982, Murray *et al.*, 1983). The numbers of other biting flies were also recorded.

3.3.1. Experiment on the response of *Glossina pallidipes* towards different unbaited traps

NG_2G, Epsilon and F3 traps were deployed in each vegetation type (i.e. Thicket with scattered bushes, Wood Grassland and Riverine forest), simultaneously over three days to assess the performance of each trap type on the catch size of *G. pallidipes,* and other biting flies. Based on the number of flies caught in each trap type, the best performing trap was selected and used for experiment three.

3.3.2. Experiment on the response of *Glossina pallidipes* towards different baited traps

Traps used in experiment one were baited with cow urine, acetone and octenol in order to investigate the best performing baits in terms of the total catches of *G. pallidipes* and other biting flies. Each odour bait was deployed with the three trap designs simultaneously over three days. Each chemical was dispensed as indicated in section 3.3.

3.3.3. Experiment on the response of *Glossina pallidipes* towards different odour bait combinations deployed with the most effective trap.

Once the most efficient trap selected, that particular trap was deployed with different combinations of cow urine, acetone and octenol to assess the performance of these baits. Some chemicals have little or no effect on their own. However, the catch increased when they were used in combination. The release rate of each chemical was the same as in experiment two. This experiment was also run over three days.

3.4. Data analysis

Daily catches with each treatment were transformed to a log (n+1) and subjected to analysis of variance (ANOVA). This helps to separate the effects of treatments from the effects of groups of days or sites and to assess the significance of differences in mean catches (Vale, 1980; Vale and Hall, 1985; FAO, 1992). Data were subjected to ANOVA using SAS procedure (SAS/STAT.95, VERSION 6.04) and the ANOVA that showed significant treatment effect was further subjected to mean separation using Duncan Multiple Range Test. Data of Tabanidae and Stomoxyinae were also analyzed using the same procedures. Sex ratio analysis was done using x^2-test by pooling data obtained from the three traps (Munyinyi, 1995).

4. RESULTS

Tsetse fly traps and odour baits were evaluated for catch performance in Nechisar National Park at three vegetation types. Three trap designs, Epsilon (E), F3 (F) and NG2G (N), were compared. The traps were unbaited and baited. Total catches and indices of catches of tsetse flies (*G. pallidipes*) are presented in Table 1, 4, 5, 6, and 10, that also show total catches of Tabanidae and Stomoxinae. In Table 2, 7, 8, 9 and 11 sex ratios of male and female tsetse flies caught by different trap types from different vegetation types are indicated. Figures 1-13 indicates age structures of both male and female *G. pallidipes* caught by each trap type at each vegetation type. Table 3 indicates the percentage of teneral and non-teneral tsetse for experiment one in Riverine forest and Wood grassland.

4.1. Species composition

Tsetse flies collected in all experiments during September 1999 - April 2000 showed that only one species, *G. pallidipes*, is present in the study areas.

4.2. Experiment on the response of *Glossina pallidipes* towards different unbaited traps

Comparisons were made between the total number of tsetse flies caught by unbaited Epsilon, F3, and NG2G traps deployed in different vegetation types. The same comparisons were made on other biting flies (Tabanidae and Stomoxinae). The experiments were conducted in Wood grassland (WGL), Riverine forest (RF) and Thicket with scattered bushes (TH). The experiment was conducted in each vegetation type.

4.2.1. Total catches

The analysis of variance for the total catches of *G. pallidipes*, Tabanidae and Stomoxyinae and the indices of increase (for the total catches of tsetse flies) under different vegetation types are presented in Table1. NG2G caught significantly more tsetse flies than Epsilon and F3. Although the difference was not statistically significant ($p > 0.05$) Epsilon caught more tsetse than F3, under all vegetation types ($p > 0.05$). Based on the indices of total catches of tsetse flies, NG2G trap caught 1.7x, 2.5x and 1.3x to that of F3 trap in Wood grassland, Riverine forest and Thickets with scattered bushes, respectively.

For the total number of Tabanidae and Stomoxinae caught by each trap type, no statistically significance difference was observed between the three trap designs ($p > 0.05$).

Table 1. Total catches of *G. pallidipes*, Tabanidae and Stomoxinae caught by different unbaited trap types at sites with different vegetation type.

Veg.	TD	Tsetse (Total)		Tabanidae	Stomoxinae
		Mean ± SE	Index+	Mean ± SE	Mean ± SE
WGL	E	0.856 ± 0.091b	1.0x	1.107 ± 0.184 a	0.668 ± 0.097 a
	F	0.835 ± 0.084 b	1.0x	1.160 ± 0.206 a	0.658 ± 0.121 a
	N	1.408 ± 0.084 a	1.7x	1.061 ± 0.127 a	0.845 ± 0.097 a
RF	E	0.562 ± 0.076 b	1.5x	0.536 ± 0.155 a	1.00 ± 0.050 a
	F	0.365 ± 0.085 b	1.0x	0.314 ± 0.100 a	0.067 ± 0.06 a
	N	0.929 ± 0.068 a	2.5x	0.514 ± 0.149 a	0.086 ± 0.05 a
TH	E	1.312 ± 0.190b	1.0x	0.838 ± 0.151 a	0.468 ± 0.133 a
	F	1.393 ± 0.107b	1.0x	0.891 ± 0.117 a	0.472 ± 0.139 a
	N	1.727 ± 0.244a	1.3x	0.605 ± 0.076 a	0.605 ± 0.076 a

Means with the same letter in a column for each vegetation type are not significantly different ($p > 0.05$)

Veg = vegetation, TD = trap design, WGL = Wood grassland, RF = Riverine forest, TH = Thicket with scattered bushes, E = Epsilon, F = F3, N = NG2G

+ = Indices of total catches of tsetse flies

4.2.2. Sex ratio

All unbaited trap types in each vegetation type caught more percentages of females than males. However, statistically significant difference ($P > 0.05$) were obtained under WGL and TH vegetation types (Table 2).

Table 2. Combined sex ratios of *G. pallidipes* caught using Epsilon, F3 and NG2G traps under different vegetation types.

Veg	Female (%)	Male (%)	x^2 (df=2)	P	LV
WGL*	83.10	16. 90	8.262	0.016	s
RF*	60.68	39.32	5.527	0.063	ns
TH*	59.10	40.90	18.658	0.000	s

Veg = vegetation, WGL = Wood grassland, RF = Riverine forest, TH = Thicket with scattered bushes, s = significant ($P \leq 0.05$), ns = not significant ($P > 0.05$), LV = level of significance

Chi-square test was done on pooled data

* Experiments were conducted in each vegetation type at different times

4.2.3. Age composition

Wing fray analysis for male flies and ovarian aging for female flies were done for tsetse flies collected from Thicket with scattered bushes, because we were not able to find proper insect dissecting kit while starting the experiment. And tsetse flies collected from Wood grassland and Riverine forest were grouped into teneral and non-teneral flies. Accordingly, age structures of both sexes collected from Thicket with scattered bushes and the percentages of teneral and non-teneral male and female flies collected from Wood grassland and Riverine forest are indicated in Figure 1 and Table 3, respectively. All traps deployed in Thicket with scattered bushes caught more flies at their early younger ages. The same traps deployed in Wood grassland and Riverine forest caught more teneral and non-teneral flies, respectively.

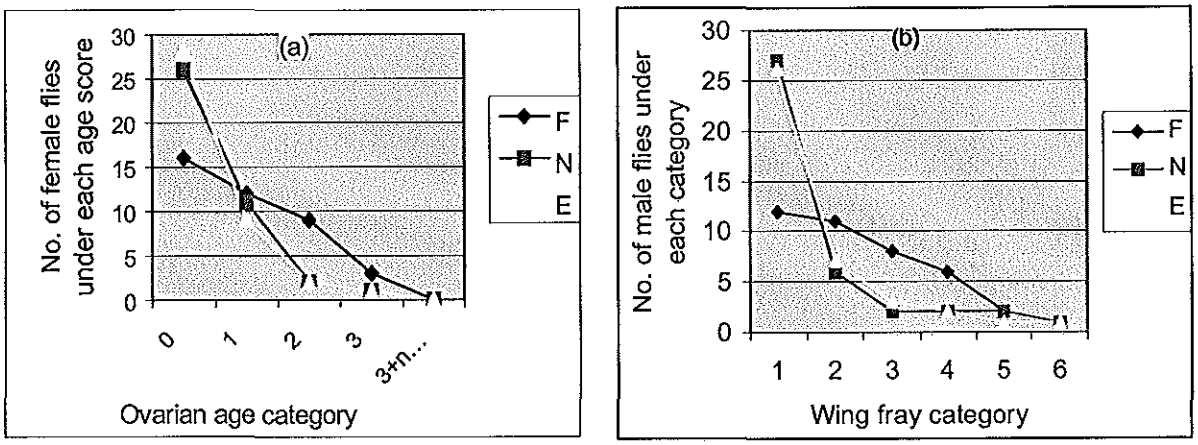

Figure 2. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F) and NG2G (N) traps from Thickets with scattered bushes between September 29, 1999 and October 01,1999. (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on their wing fray analysis

Table 3. Total catches and percentages of teneral and non-teneral male and female *G. pallidipes* caught by different unbaited trap types.

		Male				Female		
Veg	TD	Total	T	NT	%T male	T	NT	%T female
WGL*	E	72	2	10	16.67	10	50	16.67
	F	36	2	5	28.5	5	24	17.24
	N	53	4	23	14.81	4	22	15.38
RF*	E	12	2	2	50.00	4	4	50.00
	F	10	0	1	0.00	6	3	60.00
	N	34	7	9	46.67	10	7	58.82

Veg = Vegetation, TD = Trap design, WGL = Wood grassland, RF = Riverine forest, T = teneral, N = non-teneral

* Experiments were conducted in each vegetation type at different times

4.3. Experiment on the response of *Glossina pallidipes* towards different baited traps

Epsilon, F3 and NG2G traps were baited with acetone, cow urine, and octenol and compared for the number of tsetse flies captured including Tabanidae and Stomoxinae. Each odour bait was deployed with the three different trap types in each vegetation type, simultaneously. The results are shown in Tables 4, 5, and 6.

4.3.1. Total catches

Mean number of tsetse flies caught using NG2G trap baited with each odour bait was significantly higher ($p > 0.05$) than Epsilon and F3 traps deployed with the same odour baits used for NG2G under each vegetation type. Although the difference was not statistically significant ($p > 0.05$) , Epsilon trap captured more flies than F3 (Table 4, 5, and 6). Based on the indices of total tsetse catches, NG2G trap baited with acetone caught 1.4x, 1.3x and 1.2x to that of acetone baited F3 trap under Wood grassland, Riverine forest and Thicket with scattered bushes, respectively. When NG2G trap was baited with cow urine it caught 1.6x, 1.4x and 1.2x in Wood grassland, Riverine forest and Thicket, respectively. Again the same trap deployed with octenol caught 1.4x, 1.6x and 1.2x in Wood grassland, Riverine forest, and Thicket with scattered bushes, respectively. But, no significance difference ($p > 0.05$) was observed between Epsilon and F3 traps baited with the same odour baits deployed under the same vegetation types mentioned above (Table 4.).

Considering Tabanidae, no statistically significant ($p > 0.05$) was observed between traps in their performances under each vegetation type when the traps were baited with each odour bait alone. However, the number of Stomoxinae caught in NG2G trap baited with

cow urine was significantly higher ($p < 0.05$) than Epsilon and F3 traps in Thicket with scattered bushes. The same significant difference ($p < 0.05$) was also observed when traps were baited with octenol in Wood grassland and Thicket with scattered bushes. But, no such significant difference ($p > 0.05$) were observed between all trap types when they were deployed with acetone. On the other hand, no statistically significant difference ($p > 0.05$) was observed in the catches of Stomoxyinae between Epsilon and F3 traps baited with any of the odour bait under all vegetation types (Table 4, 5, and 6).

Table 4. Total catches of *G. pallidipes*, Tabanidae and Stomoxinae caught by different acetone baited trap types at sites with different vegetation types.

		Number of flies captured/ trap/ day			
Veg	TD+A	Tsetse (Total)		Tabanidae	Stomoxinae
		Mean ± SE	Index+	Mean ± SE	Mean ± SE
WGL	E +A	1.413±0.085b	1.0x	0.771±0.131a	0.638±0.170a
	F+A	1.405±0.119b	1.0x	0.897±0.100a	0.579±0.164a
	N+A	2.028±0.110a	1.4x	0.796±0.090a	1.101±0.097a
RF	E+A	1.355±0.072b	1.0x	0.638±0.109a	0.139±0.079a
	F+A	1.305±0.108b	1.0x	0.446±0.148a	0.100±0.071a
	N+A	1.667±0.109a	1.3x	0.550±0.164a	0.307±0.106a
TH	E+A	1.723±0.068b	1.0x	0.892±0.058a	0.936±0.121a
	F+A	1.729±0.080b	1.0x	0.839±0.115a	0.829±0.091a
	N+A	2.120±0.052a	1.2x	0.663±0.119a	1.020±0.147a

Means with the same letter in a column for each vegetation type are not significantly different ($P > 0.05$), Veg =Vegetation, TD+A = Trap design +acetone, WGL = Wood grassland, RF = Riverine forest, TH = Thicket with scattered bushes, E = Epsilon, F = F3, N= NG2G

+ = Indices of increase of tsetse flies

Table 5. Total catches of *G. pallidipes*, Tabanidae and Stomoxinae caught by different cow urine baited trap types at sites with different vegetation types.

		Number of flies captured / trap/ day			
Veg	TD + C	Tsetse(Total)		Tabanidae	Stomoxinae
		Mean ± SE	Index+	Mean ± SE	Mean ± SE
WGL	E+C	1.462±0.084b	1.1x	1.122±0.140a	0.645±0.151a
	F+C	1.280±0.074b	1.0x	1.042±0.129a	0.627±0.126a
	N+C	2.049±0.049a	1.6x	0.927±0.149a	0.757±0.153a
RF	E+C	0.966±0.052b	1.2x	0.868±0.149a	0.067+0.044a
	F+C	0.818±0.083b	1.0x	0.590±0.141a	0.067±0.044a
	N+C	1.173±0.054a	1.4x	0.790±0.157a	0.134±0.053a
TH	E+C	1.971±0.089b	1.0x	1.122±0.104a	0.412±0.091b
	F+C	1.920±0.110b	1.0x	1.118±0.079a	0.574±0.092b
	N+C	2.381±0.064a	1.2x	1.070±0.068a	0.773±o.116a

Means with the same letter in a column for each vegetation type are not significantly different ($P > 0.05$).

Veg = Vegetation, TD+C = Trap design +cow urine, WGL = Wood grassland, RF = Riverine forest, TH = Thicket with scattered bushes,

+ = Indices of increase of tsetse flies,

Table 6. Total catches of *G. pallidipes*, Tabanidae and Stomoxinae caught by different octenol baited trap types at sites with different vegetation types.

		Number of flies captured /trap /day			
Veg	TD + O	Tsetse (Total)		Tabanidae	Stomoxinae
		Mean ± SE	Index+	Mean ± SE	Mean ± SE
WGL	E+O	1.312±0.078b	1.2x	1.207±0.056a	0.495±0.080b
	F+O	1.132±0.091b	1.0x	1.021±0.151a	0.415±0.117b
	N+O	1.584±0.097a	1.4x	1.050±0.091a	0.793±0.138a
RF	E+O	1.027±0.104b	1.1x	0.120±0.062a	0.773±0.113a
	F+O	0.922±0.116b	1.0x	0.214±0.130a	0.714±0.084a
	N+O	1.436±0.059a	1.6x	0.134±0.053a	0.674±0.085a
TH	E+O	1.565±0.083b	1.0x	0.810±0.148a	0.703±0.129b
	F+O	1.561±0.066b	1.0x	0.818±0.128a	0.509±0.083b
	N+O	1.895±0.116a	1.2x	0.735±0.124a	0.952±0.091a

Means with the same letter in a column for each vegetation type are not significantly different ($p > 0.05$)

Veg = Vegetation, TD+O = Trap design + octenol, WGL = Wood grassland, RF = Riverine forest, TH = Thicket with scattered bushes

+= Indices of increase of tsetse flies

4.3.2. Sex ratio

In these experiments where different odour baits were used with different trap types, we found that the percentages of females caught were more than males in all vegetation types (Table 7, 8, and 9). However, statistical difference were obtained when traps were baited with acetone in WGL and RF vegetation types (Table 7)

Table 7. Combined sex ratios of *G. pallidipes* caught using acetone baited Epsilon, F3 and NG2G traps under different vegetation types.

Veg	Female (%)	Male (%)	x^2 (df=2)	P	LV
WGL*	62.54	37.46	73.820	0.000	s
RF*	62.83	37.17	10.065	0.007	s
TH*	59.95	40.05	1.902	0.386	ns

Veg= Vegetation, WGL = Wood grassland, RF = Riverine forest, TH = Thicket with scattered bushes, ns = not significant ($P > 0.05$), s = significant ($P \leq 0.05$), LV = level of significance

Chi-square test was done on pooled data

* Experiments were conducted in each vegetation type at different times

Table 8. Combined sex ratios of *G. pallidipes* caught using cow urine baited Epsilon, F3 and NG2G traps under different vegetation types.

Veg	Female (%)	Male (%)	x^2 (df=2)	P	LV
WGL	64.00	36.00	2.573	0.272	ns
RF	65.00	35.00	1.872	0.392	ns
TH	60.32	39.68	0.078	0.962	ns

Veg = Vegetation, WGL = Wood grassland, RF = Riverine forest, TH = Thicket with scattered bushes, ns = not significant (P> 0.05), LV = level of significance

Chi-square test was done on pooled data

* Experiments were conducted in each vegetation type at different times

Table 9. Combined sex ratios of *G. pallidipes* caught using octenol baited Epsilon, F3 and NG2G under different vegetation types.

Veg	Female (%)	Male (%)	x^2-test (df=2)	P	LV
WGL*	70.66	29.34	0.582	0.747	ns
RF*	67.11	32.89	3.826	0.148	ns
TH*	61.92	38.08	4.314	0.116	ns

Veg = Vegetation, WGL = Wood grassland, RF = Riverine forest, TH = Thicket with scattered bushes, ns = not significant (P> 0.05), LV = level of significance

Chi- square test was done on pool data

* Experiments were conducted in each vegetation type at different times

4.3.3. Age composition

Age structures of male and female *G. pallidipes* are presented in Figures 2-10 based on their wing fray analysis (for male flies) and ovarian aging (for female flies). All trap types deployed with acetone in Wood grassland caught more female flies at their `younger ages and more males at their older ages (Figure 2). In Riverine forest, more male older and younger ages and female flies of both older and younger ages were caught (Figure 3). Age composition of male and female *G. pallidipes* caught by different trap types baited with cow urine (in Wood grassland and Thicket with scattered bushes) and octenol (in Wood grassland and Riverine forest) caught flies at their early ages (Figures 5, 7, 8, and 9). However, in Riverine forest and Thicket with scattered bushes, the proportion of both sexes of early and older ages were smaller (Figures 6 and 10).

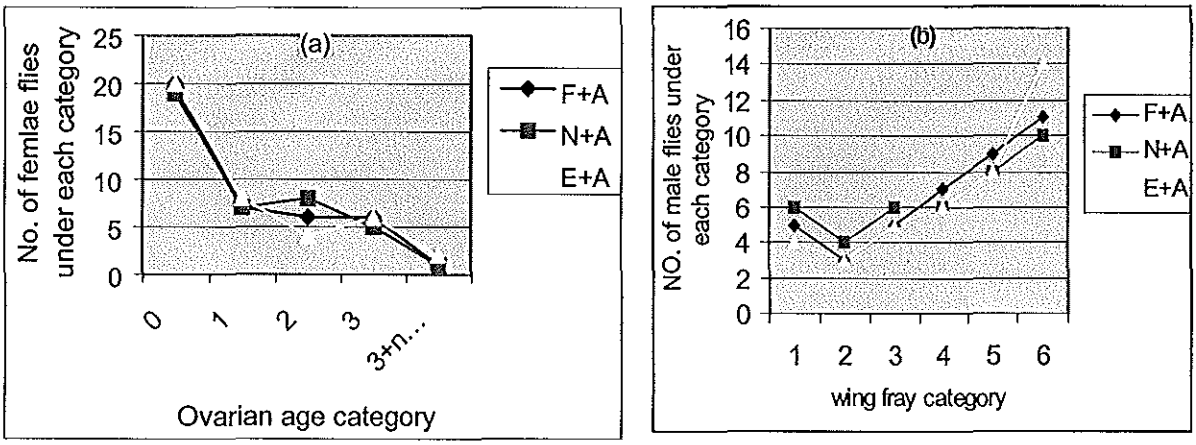

Figure 3. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F) and NG2G (N) traps deployed with acetone (A) in Wood grassland between December, 31,1999-January, 02, 2000. (a) Female flies based on ovarian aging (b) Male tsetse flies based on their wing fray analysis

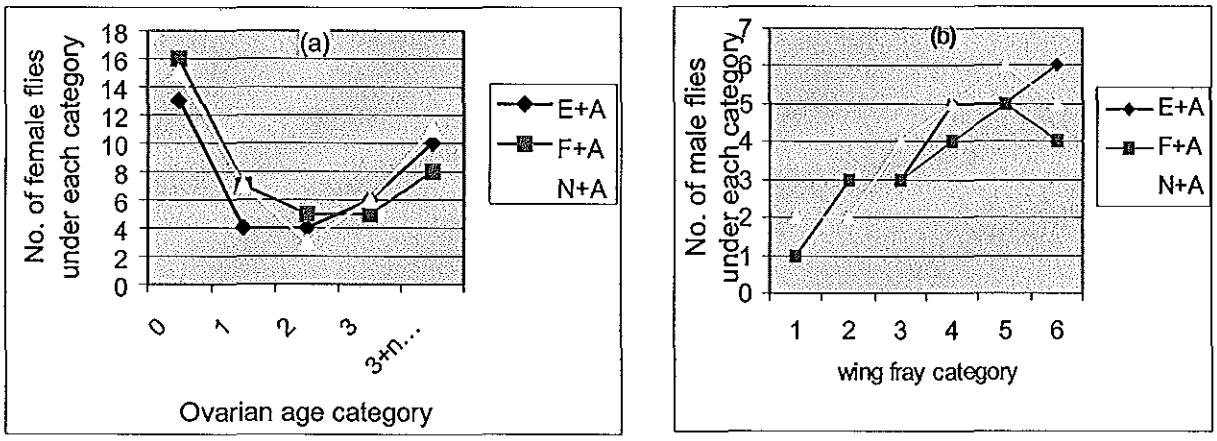

Figure 4. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F) and NG2G (N) traps deployed with acetone (A) in Reverine forest between January, 03- 05, 2000. (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on their wing fray analysis

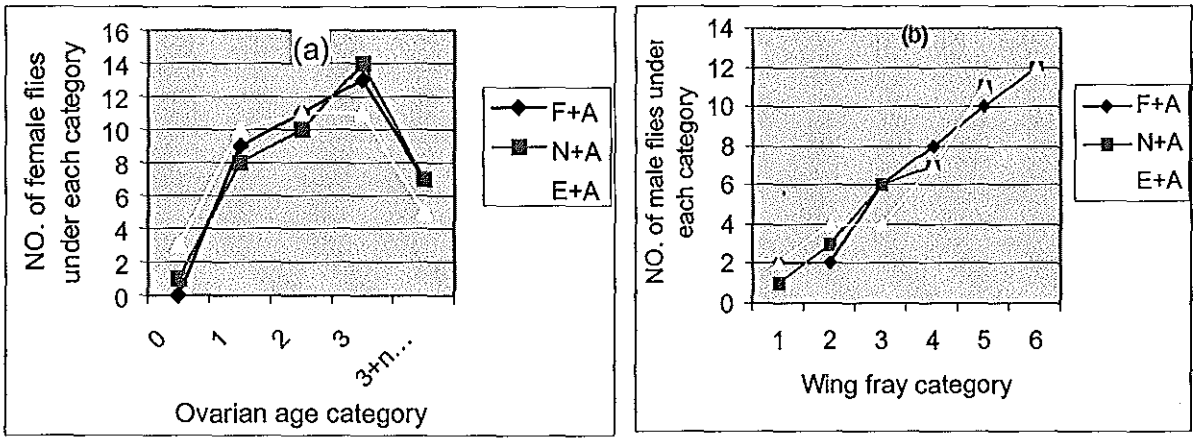

Figure 5. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F) and NG2G (N) traps deployed with acetone (A) in Thicket with scattered bushes between January, 28- 30, 2000. (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on their wing fray analysis

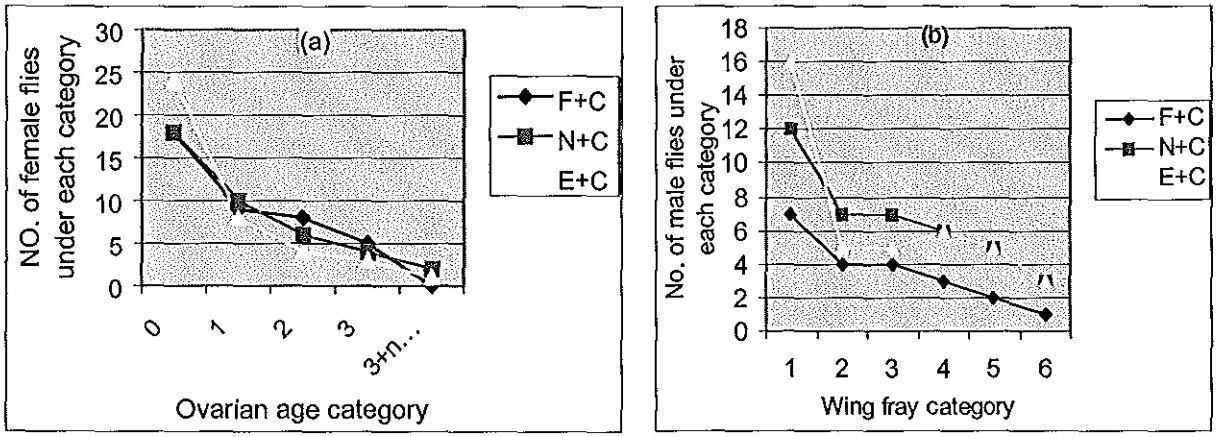

Figure 6. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F) and NG2G (N) traps deployed with Cow urine (C) in Wood grassland between December 2, - 04, 1999. (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on their wing fray analysis

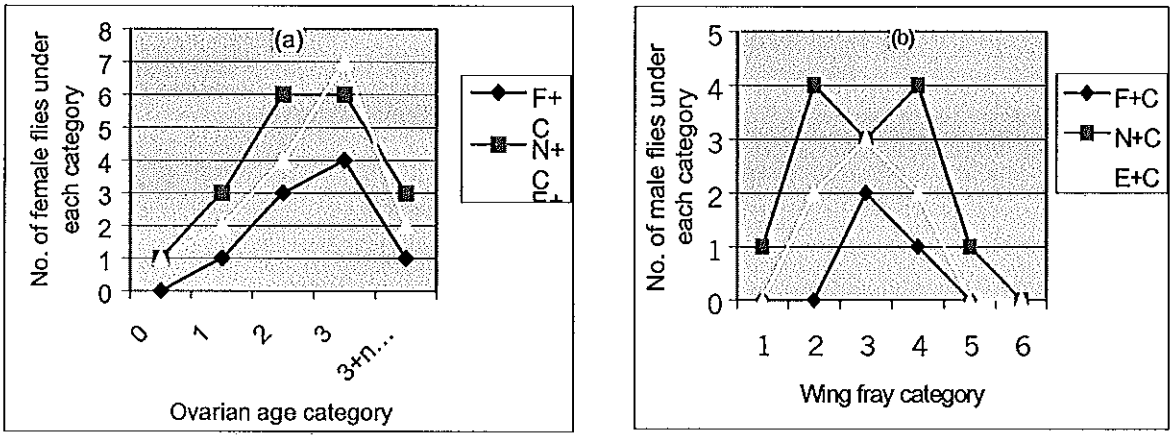

Figure 7. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F) and NG2G (N) traps deployed with Cow urine (C) in Reverine forest between December 08 - 10, 1999. (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on their wing fray analysis

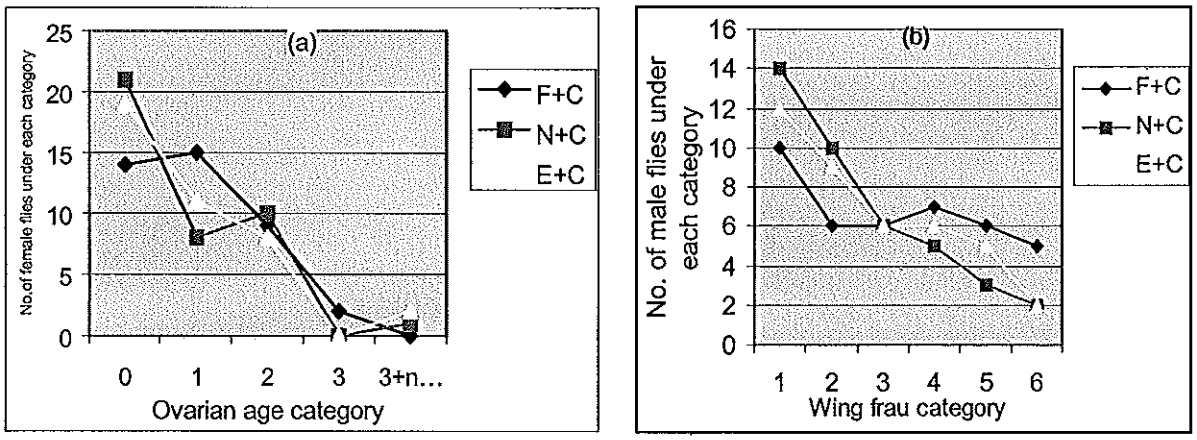

Figure 8. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F) and NG2G (N) traps deployed with cow urine (C) in Thicket with scattered bushes between December 08 - 10, 1999. (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on their wing fray analysis

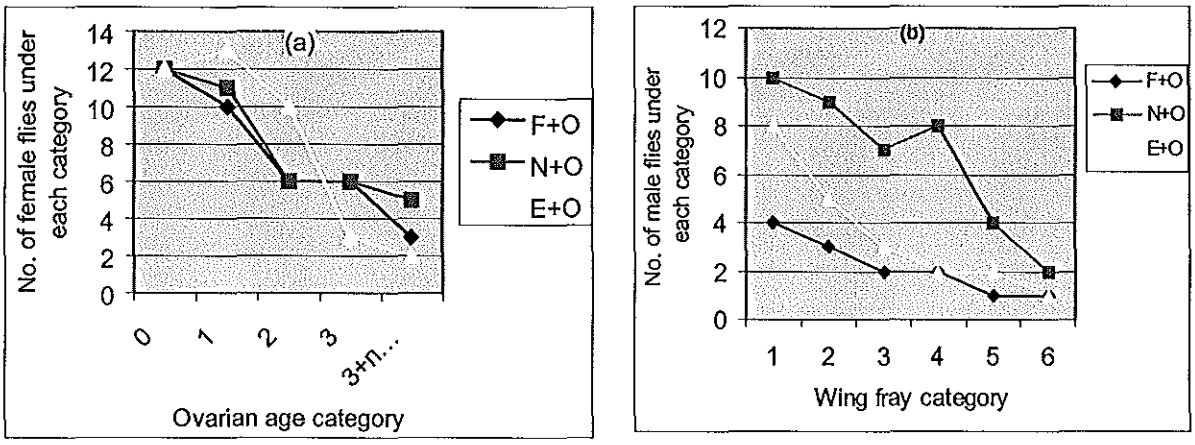

Figure 9. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F) and NG2G (N) traps deployed with octenol (O) in Wood grassland between December 08 - 10, 1999. (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on their wing fray analysis

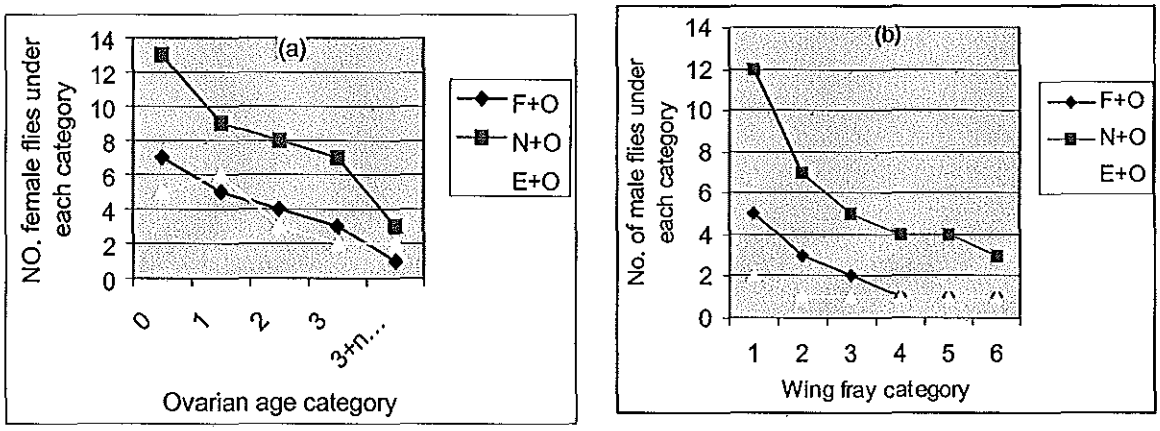

Figure 10. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F), and NG2G (N) traps deployed with octenol (O) in Reverine forest between January, 31-February 02, 2000. (a) Female flies based on ovarian aging (b) Male flies based on wing fray analysis

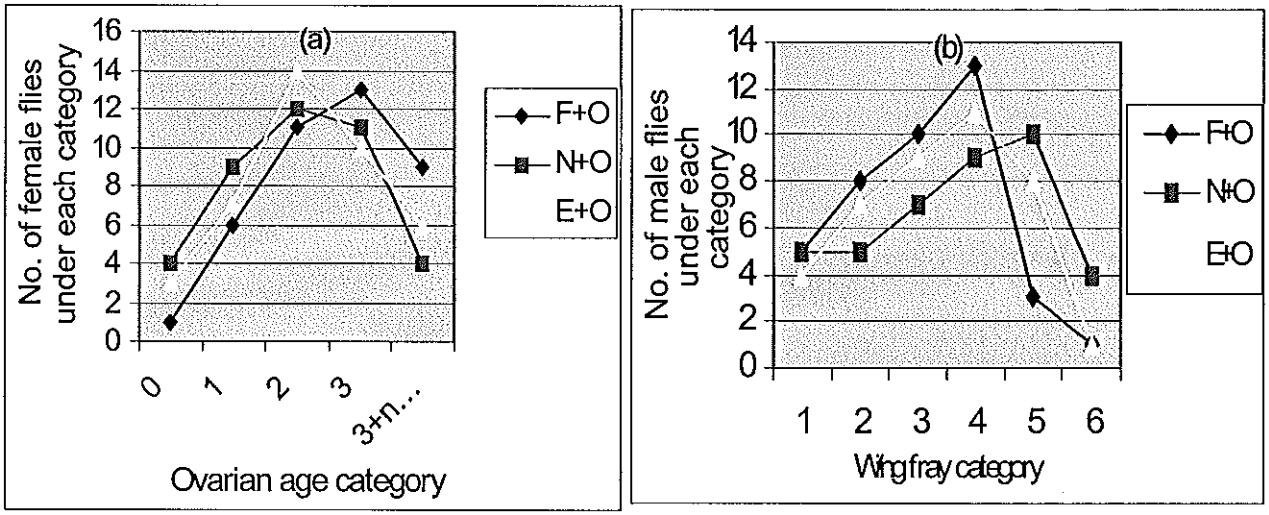

Figure 11. Age distributions of *G. pallidipes* caught by Epsilon (E), F3 (F), and NG2G (N) traps deployed with octenol (O) in Thicket with scattered bushes between January, 31- February 02, 2000. (a) Female flies based on ovarian aging (b) Male flies based on wing fray analysis

4.4. Experiment on different combinations of different odour baits deployed with the most effective trap in field situations.

After conducting experiment one and experiment two it was found that both unbaited and baited NG2G traps were more effective than Epsilon and F3 traps in both experiments. Then, we used NG2G trap for experiment three to assess the performance of different combinations of acetone, cow urine and octenol.

4.4.1. Total catches

NG2G trap deployed with acetone + cow urine (A+C) and acetone +cow urine + octenol (A+C+O) caught significantly ($P < 0.05$) more tsetse flies than those deployed with acetone + octenol (A+O) and octenol + cow urine (O+C) under all vegetation types. However, no such significance difference ($P > 0.05$) was observed between NG2G traps baited with acetone + cow urine and acetone + cow urine + octenol. On the other hand, in Riverine forest and Thicket with scattered bushes no statistically significant difference ($P > 0.05$) was observed between NG2G traps baited with acetone + octenol and octenol + cow urine. But in Wood grassland, octenol + cow urine caught significantly ($P < 0.05$) more tsetse than acetone + octenol.

Indices of fly catches were estimated for different combinations of odour baits. Since acetone + octenol caught least number of flies, it is chosen as basis of comparison. Acetone + cow urine and acetone + cow urine + octenol gave 1.2x compared to acetone + octenol (Table 10) under all vegetation types. This shows that the combination of octenol with cow urine and acetone did not improve the catch index, i.e. it remains 1.2x. NG2G traps baited with octenol + cow urine caught 1.1x to that of NG2G traps baited with acetone + octenol in Wood grassland although no such difference ($P>0.05$) was observed under Riverine forest and Thicket with scattered bushes (Table 10).

With regard to Tabanidae, NG2G trap deployed with acetone + cow urine + octenol and octenol + cow urine caught higher number of Tabanidae than NG2G traps deployed with acetone + cow urine and acetone + octenol in all vegetation types. But, no such significance

difference ($p > 0.05$) was observed between NG2G traps baited with acetone + cow urine + octenol and octenol + cow urine.

For Stomxyinae, different results were observed between different combinations of odour baits in line with the type of vegetation. In Riverine forest no significant difference ($P > 0.05$) was observed among traps baited with all combinations of odour baits. In Thicket with scattered bushes, on the other hand, NG2G traps baited with acetone +cow urine and acetone +cow urine + octenol caught significantly ($P < 0.05$) more number of *Stomoxys* than that baited with acetone + octenol and octenol + cow urine. But, in Wood grassland NG2G traps baited with acetone +cow urine and acetone + octenol caught the highest and the least number ($P > 0.05$) of Stomoxyinae. NG2G traps deployed with acetone + cow urine + octenol and octenol + cow urine caught intermediate number of Stomoxyinae.

Table 10. Total catches of *G. pallidipes*, Tabanidae and Stomoxyinae caught by NG2G traps deployed with different combinations of odour baits under different vegetation types.

		Number of flies caught / trap / day			
Veg.	N+C	Tsetse (Total)		Tabanidae	Stomoxyinae
		Mean ± SE	Index+	Mean ± SE	Mean ± SE
WGL	A+C	1.781±0.103a	1.2x	0.854±0.089b	1.520±0.025a
	A+C+O	1.825±0.125a	1.2x	1.349±0.080a	1.366±0.102b
	A+O	1.479±0.103c	1.0x	0.870±0.117b	1.154 ±0.089c
	O+C	1.625±0.094b	1.1x	1.268±0.107a	1.367±0.070b
RF	A+C	2.008±0.059a	1.2x	0.959±0.107b	0.631±0.106a
	A+C+O	2.048±0.069a	1.2x	1.317±0.082a	0.585±0.048a
	A+O	1.688±0.065b	1.0x	0.946±0.085b	0.652±0.091a
	O+C	1.696±0.071b	1.0x	1.396±0.075a	0.583±0.096a
TH	A+C	2.404±0.077a	1.2x	1.024±0.037b	1.479±0.056a
	A+C+O	2.443±0.053	1.2x	1.276±0.101a	1.382±0.097a
	A+O	2.130±0.089b	1.0x	0.937±0.141b	1.181±0.111b
	O+C	2.134±0.078b	1.0x	1.272±0.074a	1.299±0.151b

Means with the same letter with in a column for each vegetation are not significantly different ($p > 0.05$),
Veg = vegetation, N+C = NG2G+combination of different odours, A+C = acetone +cow urine, A+C+O = acetone + cow urine + octenol, O+C = octenol+cow urine, WGL =Wood grassland, RF = Riverine forest, TH = Thicket with scattered bushes
+ = Indices of total catches of tsetse flies

4.4.2. Sex ratio

Significance difference ($P < 0.05$) was observed in the number of male and female *G. pallidipes* caught by NG2G traps baited with different combinations of acetone, cow urine and octenol in WGL and TH. Although thePercentages of females are higher than males in RF, there was no significant difference ($P > 0.05$) (Table 11).

Table 11. Combined sex ratios of *G. pallidipes* caught using NG2G trap baited with different combinations of acetone, cow urine and octenol under different vegetation types.

Veg.	Female (%)	Male (%)	x^2 (df=3)	P	LV
WGL	90.50	9.50	374.210	0.000	s
RF	65.38	34.52	2.892	0.409	ns
TH	60.57	39.43	375.640	0.000	s

Veg = vegetation, WGL = Wood Grassland, RF = Riverine forest, TH = Thicket with scattered bushes, ns = not significant ($P > 0.05$), s = significant ($P \leq 0.05$), LV = level of significance

Chi-square test was done on pooled data

*Experients were conducted in different vegetation at different times

4.4.3. Age composition

The number of tsetse flies caught in all combinations of odour baits with NG2G traps in different vegetation types increased as the flies got older. Similar trends were observed for all odour combinations (Figure 12, 13 and 14).

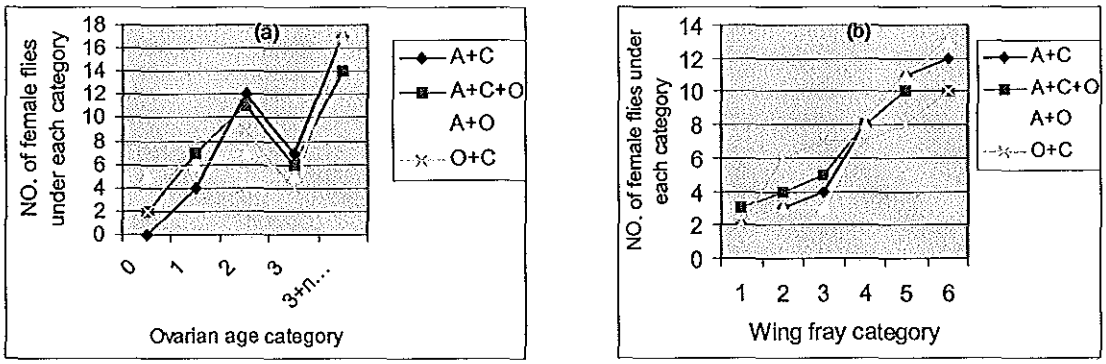

Figure 12. Age distributions of *G. pallidipes* caught by NG2G traps deployed with different combinations of acetone (A), cow urine (C) and octenol (O) in Wood grassland between April 04 and April 07, 2000, (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on wing their wing fray analysis

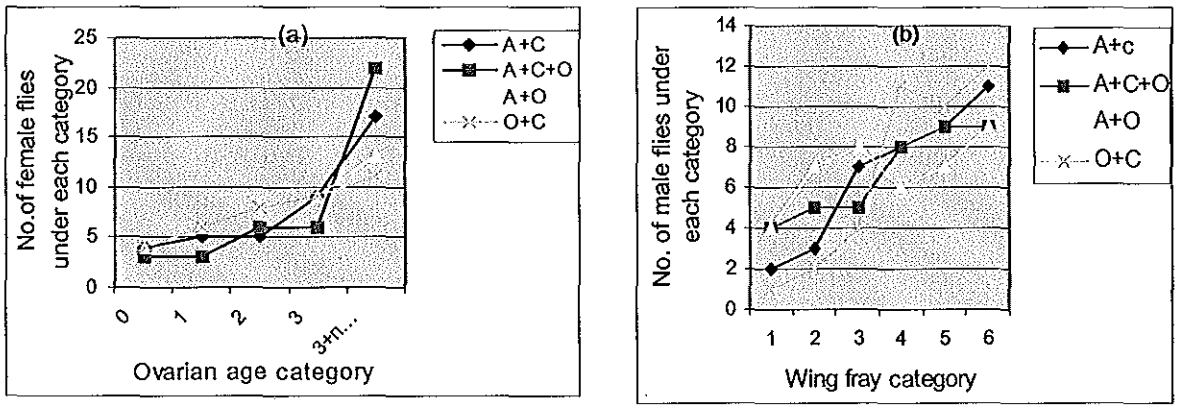

Figure 13. Age distributions of *G. pallidipes* caught by NG2G traps deployed with different combinations of acetone (A), cow urine (C) and octenol (O) in Riverine forest between February, 04 - 07, 2000, (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on wing fray analysis.

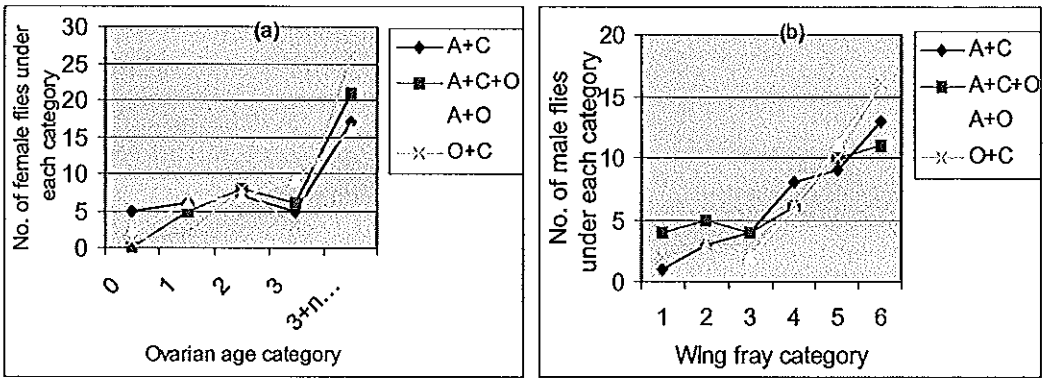

Figure 14. Age distributions of *G. pallidipes* caught by NG2G traps deployed with different combinations of acetone (A), cow urine (C) and octenol (O) in Thicket with scattered bushes between April, 08 and April 11, 2000, (a) Female tsetse flies based on ovarian aging (b) Male tsetse flies based on wing fray analysis.

5. DISCUSSIONS

Trap catches are influenced by season, capture device, experimental sites, and the qualitative and quantitative make up of the odour source. Fly activities, which vary depending on extrinsic factors (such as temperature and humidity), and intrinsic factors (such as sex, age and hunger stage), also affect the catch size (Gough and Hall, 1995). Considering these factors latin square design was used to reduce residual variance due to the effect of days and sites. However, trap catches are often biased because the particular behaviour of the flies is affected by those factors mentioned above.

A preliminary study of species identification conducted on the same area indicated that *G. pallidipes* is the only species found in Nechisar National park (tsetse Control and Eradication Project, Personal communication). The same result is found in the present study.

The effect of trap size, shape and colour on trap catches have been observed by many workers and it has been proved that different *Glossina species* have preferences towards different trap types (Flint, 1985). Brightwell *et al.* (1987), for instance, found that NG2G version traps are three times more effective the biconical traps for catching *G. pallidipes*. The preferences *of G. pallidipes* were also observed here with NG2G traps, Epsilon and F3 traps. In the first two experiments conducted in Wood grassland, Riverine forest and Thicket with scattered bushes, both unbaited and baited NG2G traps were found to be consistently more effective than Epsilon and F3 traps in capturing *G. pallidipes*. Although the difference was not significant, Epsilon traps caught more tsetse flies than F3 traps in all vegetation types. Considering trap size, NG2G trap is larger than Epsilon and F3 traps. The shape is also quite different from that

of Epsilon and F3 trap designs. Epsilon and F3 also have differences in size and shape. The addition of odour baits to the respective trap types did not improve trap catches. For example, in Thicket with scattered bushes catch index of NG2G trap was 1.3x, 1.2x, 1.2x, 1.2x for traps with no odour bait, acetone, cow urine and octenol, respectively. Thus, the results suggest that trap shape and size contribute much to their performances than odour bait and trap interactions.

Further investigations on the performances of NG2G traps baited with different combinations of acetone, cow urine and octenol, showed that NG2G traps deployed with acetone + cow urine + octenol, and acetone + cow urine caught significantly more *G. pallidipes* than those NG2G traps deployed with acetone + octenol and cow urine + octenol in all vegetation types. Deransfield *et al.,* (1986) found similar effects of acetone + cow urine and acetone + octenol with biconical traps on the same species. According to Baylis and Nambiro (1993) octenol does have very little effect, either on its own, or in combination with acetone. The use of octenol in conjunction with cow urine gives small but significant increases of trap catches for *G. pallidipes* (Brightwell *et al.*, 1991).

Mean catches were significantly more when cow urine was combined with acetone than cow urine combined with octenol. However, the addition of octenol with cow urine, cow urine + acetone improved the trap catch but not significantly as compared to mean catch obtained when cow urine combined with acetone in each vegetation type. This suggests that octenol acts synergistically when used with cow urine + acetone. This synergism is suggested by a comparison of catch indices, but has not been demonstrated statistically. Traps baited with

cow urine + octenol were more effective than those of traps baited with acetone + octenol in Wood grassland. This was not observed in the case of Riverine forest and Thicket with scattered bushes.

Comparison of trap designs (experiment one) showed that trap designs have no effect on the catch of Tabanidae. Also odour baits used individually with traps have not improved catches of Tabanidae (experiment two). However, combinations of odour baits have shown significant effect in catching Tabanidae. This suggests that combinations of odour baits have synergetic effect so that more Tabanidae are captured as compared to the number of Tabanidae caught in experiment one and experiment two. Vale (1984, cited in Vale and Hall, 1985) explained that Tabanidae, Stomoxyinae and other Muscoids do not have a strong response to visual baits. Similar effects were observed in the present study that combinations of odour baits are more effective in attracting Tabanidae than different trap types. The indication that NG2G trap baited with acetone + cow urine + octenol and cow urine + octenol catching more tabanides than the same types of traps deployed with acetone + octenol and acetone + cow urine, on the other hand, suggests that octenol acts synergistically with cow urine on Tabanidae. However, it requires further research.

With regard to Stomoxyinae, no significance difference was observed between unbaited NG2G, Epsilon and F3 traps in experiment one. However, performances of different odour baits both alone (except acetone) and in combinations varied in line with the type of vegetation. For example, in Riverine forest no significant difference was observed in the number of *stomoxys* caught by different trap types baited with each odour bait and/ or with

their combinations. On the other hand, the number of *stomoxys* caught in NG2G traps baited with cow urine (in Thicket with scattered bushes) and NG2G traps baited with octenol (in Wood grassland and Thicket with scattered bushes) was higher than Epsilon and F3 traps. In experiment three, NG2G traps deployed with acetone +cow urine (in Wood grassland) and NG2G traps deployed with acetone +cow urine and acetone +cow urine +octenol also caught more number of *stomoxys* than traps of the same type deployed with acetone + octenol, cow urine + octenol (in Wood grassland) and acetone +cow urine and acetone + octenol (in Thicket with scattered bushes). We do not know exactly how *stomoxys* respond towards different odour baits released near traps deployed in different vegetation types. Our observations suggest that *stomoxys* show strong responses towards acetone and cow urine both alone and in combination. However, further studies are needed if we are to fully understand the responses of *stomoxys* towards different odour baits.

Sex ratios differ according to the population being sampled. Since trapping devices get only the active section of the population, the ratio can indicate the differences in the activity patterns of the population. Activity pattern may be related to the physiology and behavior of the fly in response to climatic and other conditions (Owaga, 1985). In the present study, we found that the percentages of females are higher than males in all experiments. The level of significant difference in trap catches varies with vegetation and bait types. On the other hand the works of Turner (1987) and Owaga (1989) in Kenya indicated that traps are relatively more effective in catching males than females. These different results obtained in Kenya and the present study (in Ethiopia) probably reflect differences in fly behaviour, vegetation and climatic conditions of the two countries.

It was noted that the age composition of both sexes from experiment one and experiment three had similar age structure, in that unbaited traps caught more younger flies and NG2G trap baited with different composition of acetone, cow urine and octenol caught more older flies. Traps baited with each odour bait, on the other hand, caught more younger females and older *G. pallidipes*. According to Owaga and Challier (1985), trap catches are representative of the fly population, seeking blood meal, resting sites, larviposition sites (for females), or mate (for males). Thus, our results might be related to these factors. As cited in Owaga (1989), the work of Jack (1985) showed the reluctance of young *G. pallidipes* to enter traps and the biasness of traps against teneral and young immediate post teneral flies. This part of the study was designed to have base line information for further study

6. CONCLUSIONS AND FUTURE RESEARCH

This study underlines the parts played by different trap types and different odour baits in attracting *G. pallidipes* in a vegetation type of the Nechisar National Park, southern Ethiopia. In all experiments, NG2G trap was found to be more effective in catching *G. pallidipes* than Epsilon

and F3 traps. Although the difference was not significant, Epsilon appeared to be more effective than F3 trap. Acetone and cow urine, individually and in combination, found to be more attractive for tsetse flies than octenol. However, odour baits did not increase the indices of trap catches. The relatively higher catches obtained using NG2G and cow urine both alone and in combination suggests an opportunity to use NG2G and cow urine as bait for community based tsetse management. NG2G trap offers some important advantageous over Epsilon and F3 traps because it is cheaper to construct and is easier to deploy. The availability of cow urine in large quantities with no cost to the rural communities will make fly trapping potentially feasible.

All unbaited traps caught smaller proportion older flies of both sexes. NG2G traps baited with different combinations of different odour baits caught higher proportion of older flies. When traps were deployed with each odour bait, they caught higher proportion of younger female flies and higher proportion of older male flies. However, the percentages of females were higher than males.

The response of Tabanidae towards different combinations of odour baits was found to be stronger than unbaited trap and traps baited with individual baits. A blend of cow urine and

octenol appeared to be more attractive for tabanides than any combinations of acetone, cow urine and octenol. The response of stomoxys towards odour baits, especially towards acetone and cow urine both singly and in blend, also seemed to be stronger than traps alone although the results varied in line with vegetation types. Catching of Tabanidae and Stomoxyinae during tsetse fly control enhance the reduction of trypanosomosis transmission as both tabanides and stomoxys transmit trypanosomosis mechanically.

Present results highlighted the feasibility of identifying effective trap designs and odour baits for tsetse control in the study area. The full benefit of such traps and odour baits depends up on our

understanding about the ecology and behavior of *G. pallidipes*. So, further research might usefully study the responses of *G. pallidipes* towards:

i. optimum trap deployment strategy (height of trap mounting, position of odour sources) and effect of trap sites (shady areas, sunny areas, open areas, etc.)

ii. different traps and odour baits in different season of a year in order to develop efficient control strategies using traps and odour baits.

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Appendix 1. Analysis of variance for the performance of different unbaited trap designs in catching *G. pallidipes* from different vegetation types of Nechisar National Park.

Veg.	Source of Variation	Male DF	Male SS	Male MS	Male P	Female DF	Female SS	Female MS	Female P	Total DF	Total SS	Total MS	Total P
1	Rep	2	0.1366	0.0683	0.1851	2	0.3395	0.1697	0.0473	2	0.3267	0.1633	0.0587
	Site (Rep)	6	0.5691	0.09486	0.0642	6	0.4854	0.0809	0.1663	6	0.4733	0.0789	0.1963
	Day	2	0.0098	0.0049	0.8734	2	0.0801	0.0401	0.4279	2	0.0523	0.0262	0.5834
	TD	2	1.5039	0.7519	0.0001	2	1.6340	0.8170	0.0001	2	1.9000	0.9500	0.0001
2	Rep	2	0.0880	0.0440	0.2120	2	0.1504	0.0752	0.2530	2	0.1740	0.0870	0.2724
	Site (Rep)	6	0.0959	0.0160	0.7040	6	0.1296	0.0216	0.8427	6	0.1895	0.0316	0.7846
	Day	2	0.0121	0.0060	0.7912	2	0.0486	0.0243	0.6225	2	0. 0466	0.0233	0.6886
	TD	2	1.5434	0.7718	0.0001	2	0.3362	0.6734	0.0087	2	1.4741	0.7370	0.0009
3	Rep	2	0.4470	0.2235	0.0114	2	0.3024	0.1512	0.1483	2	0. 2119	0.1096	0.6495
	Site (Rep)	6	0.7325	0.1221	0.0227	6	0.9137	0.1523	0.1040	6	1.3914	0.2319	0.4962
	Day	2	0.0400	0.0200	0.5834	2	0.2137	0.1069	0.2465	2	2.6585	1.3292	0.0183
	TD	2	1.4243	0.7121	0.0001	2	2.8526	1.4263	0.0001	2	0.8799	0.4399	0.2036

Veg = vegetation, 1 = Wood grassland, 2 = Riverine forest, 3 = Thicket with scattered bushes, REP = replication, TD = trap design

Appendix 2. Analysis of variance for the performance of different trap designs baited with acetone in catching *G. pallidipes* from different vegetation types of Nechisar National Park.

Veg.	Source of Variation	Male DF	Male SS	Male MS	Male P	Female DF	Female SS	Female MS	Female P	Total DF	Total SS	Total MS	Total P
1	Rep	2	1.1110	0.5555	0.0020	2	0.5689	0.2844	0.0337	2	0.7885	0.3943	0.0096
	Site (Rep)	6	0.6778	0.1130	0.1283	6	0.5285	0.0881	0.2996	6	0.5917	0.0986	0.2059
	Day	2	0.2082	0.1041	0.1899	2	0.2004	0.1002	0.2492	2	0.2014	0.1007	0.2209
	TD+A	2	1.7853	0.8927	0.0002	2	2.4670	1.2335	0.0001	2	2.2954	1.1477	0.0001
2	Rep	2	0.4844	0.2422	0.0242	2	0.9508	0.4754	0.0001	2	0.8526	0.4263	0.0003
	Site (Rep)	6	0.6199	0.1034	0.1191	6	0.9897	0.1649	0.0021	6	0.8134	0.1356	0.0073
	Day	2	0.0068	0.0033	0.9337	2	0.0095	0.0047	0.8351	2	0.0101	0.0050	0.8386
	TD+A	2	0.6738	0.3369	0.0085	2	0.6981	0.3491	0.0006	2	0.6938	0.3469	0.0008
3	Rep	2	0.5720	0.2860	0.0001	2	0.3665	0.1832	0.0004	2	0.4559	0.2280	0.0001
	Site (Rep)	6	0.1126	0.0188	0.1418	6	0.2062	0.0344	0.0578	6	0.1642	0.0274	0.0654
	Day	2	0.3582	0.1791	0.0001	2	0.1427	0.0713	0.0160	2	0.2231	0.1116	0.0016
	TD+A	2	0.7814	0.3907	0.0001	2	0.9889	0.4945	0.0001	2	0.9306	0.4653	0.0001

Veg= Vegetation, 1 = Wood grassland, 2 = Riverine forest, 3 = Thicket with scattered bushes, REP = replication, TD +A = traps baited with acetone

Appendix 3. Analysis of variance for the performance of different trap designs baited with cow urine in catching *G. pallidpes* from different vegetation types of Nechisar National Park.

Veg.	Source of Variation	DF	Male SS	MS	P	DF	Female SS	MS	P	DF	Total SS	MS	P
1	Rep	2	0.0730	0.0365	0.5815	2	0.0055	0.0028	0.9523	2	0.0158	0.0079	0.8579
	Site (Rep)	6	0.4562	0.0760	0.3739	6	0.1582	0.0264	0.8224	6	0.2330	0.0388	0.6130
	Day	2	0.3979	0.1990	0.0784	2	0.0659	0.0330	0.5717	2	0.1023	0.0511	0.3926
	TD+C	2	2.4782	1.2391	0.0001	2	2.9397	1.4698	0.0001	2	2.9049	1.4524	0.0001
2	Rep	2	0.2488	0.1244	0.0905	2	0.1036	0.0518	0.1924	2	0.1591	0.0795	0.0709
	Site (Rep)	6	0.3837	0.0639	0.2569	6	0.0991	0.0165	0.7313	6	0.3220	0.0537	0.1090
	Day	2	0.0216	0.0108	0.7833	2	0.1954	0.0977	0.0583	2	0.0665	0.0333	0.2924
	TD+C	2	0.3559	0.1780	0.0397	2	0.1302	0.0651	0.1332	2	0.5700	0.2850	0.0011
3	Rep	2	0.4775	0.2088	0.0271	2	0.4235	0.2117	0.0302	2	0.4086	0.2043	0.0302
	Site (Rep)	6	0.5535	0.0922	0.1206	6	0.7312	0.1219	0.0649	6	0.6357	0.1059	0.0876
	Day	2	0.0283	0.0142	0.7310	2	0.0866	0.0433	0.4181	2	0.0638	0.0319	0.5092
	TD+C	2	1.2157	0.6078	0.0005	2	1.0990	0.5495	0.0010	2	1.1499	0.5750	0.0007

Veg = Vegetation, 1 = Wood grassland, 2 = Riverine forest, 3 = Thicket with scattered bushes, REP = replication, TD = trap baited with cow urine

Appendix 4. Analysis of variance for the performance of different trap designs baited with octenol in catching *G. pallidipes* from different vegetation types of Nechisar National Park.

Veg.	Source of Variation	DF	Male SS	MS	P	DF	Female SS	MS	P	DF	Total SS	MS	P
1	Rep	2	0.1974	0.0987	0.3907	2	0.6366	0.3183	0.0032	2	0.5353	0.2677	0.0181
	Site (Rep)	6	0.3612	0.060	0.7164	6	0.5180	0.0863	0.0824	6	0.4710	0.0785	0.2225
	Day	2	0.0548	0.0274	0.7604	2	0.0337	0.0168	0.6348	2	0.0235	0.0117	0.7919
	TD+O	2	0.6820	0.3410	0.0595	2	0.9098	0.4549	0.0007	2	0.9288	0.4644	0.0026
2	Rep	2	0.3129	0.1564	0.0514	2	0.0485	0.0242	0.6967	2	0.1409	0. 0704	0.3660
	Site (Rep)	6	0.7171	0.1195	0.0513	6	0.6765	0.1127	0.1876	6	0.8011	0.1335	0.1261
	Day	2	0.0845	0.0424	0.3919	2	0.1450	0.0725	0.3571	2	0.1507	0.0754	0.3430
	TD+O	2	1.6668	0.8334	0.0001	2	0.9395	0.4697	0.0071	2	1.3258	0.6629	0.0019
3	Rep	2	0.5745	0.2873	0.0001	2	0.5838	0.2919	0.0002	2	0.6215	0.3108	0.0001
	Site (Rep)	6	0.8036	0.1339	0.0003	6	0.7643	0.1274	0.0013	6	0.8234	0.1372	0.0003
	Day	2	0.0954	0.0477	0.0663	2	0.1528	0.0764	0.0363	2	0.1309	0.0655	0.0295
	TD+O	2	0.5062	0.2531	0.0002	2	0.7845	0.3922	0.0001	2	0.6830	0.3415	0.0001

Veg= Vegetation, 1= Wood grassland, 2= Riverine forest, 3= Thicket with scattered bushes, REP= replication, TD= traps baited with octenol

Appendix 5. Analysis of variance for the performance of NG2G trap baited with different combinations of odour baits in catching *G. Pallidipes* from *different* vegetation of Nechisar National Park.

Veg.	Source of Variation	DF	Male SS	MS	P	DF	Female SS	MS	P	DF	Total SS	MS	P
1	Rep	2	2.8988	1.4494	0.0001	2	3.4521	1.7260	0.0001	2	3.6218	1.8109	0.0001
	Site (Rep)	9	1.1265	0.1252	0.0087	9	1.1765	0.1307	0.0042	9	1.2202	0.1356	0.0030
	Day	3	0.1620	0.0540	0.2755	3	0.0609	0.0203	0.6515	3	0.0988	0.0329	0.4495
	TD+CO	3	0.5842	0.1947	0.0070	3	1.1647	0.3882	0.0001	3	0.8980	0.2993	0.0004
2	Rep	2	0.7322	0.3661	0.0006	2	0.2930	0.1465	0.0001	2	0.4025	0.2012	0.0001
	Site (Rep)	9	1.5789	0.1754	0.0007	9	1.4440	0.1604	0.0001	9	1.3671	0.1519	0.0001
	Day	3	0.2786	0.0929	0.0850	3	0.2129	0.0710	0.0010	3	0.1660	0.0553	0.0124
	TD+CO	3	1.3563	0.4521	0.0001	3	1.3100	0.4367	0.0001	3	1.3649	0.4550	0.0001
3	Rep	2	1.8011	0.9006	0.0001	2	0.8141	0.4070	0.0001	2	1.0793	0.5396	0.0001
	Site (Rep)	9	1.0192	0.1132	0.0247	9	1.1410	0.1268	0.0001	9	1.0543	0.1171	0.0002
	Day	3	0.4144	0.1381	0.0391	3	0.3328	0.1109	0.0036	3	0.3204	0.1068	0.0065
	N+CO	3	0.7608	0.2536	0.0031	3	1.1382	0.3794	0.0001	3	1.0077	0.3359	0.0001

Veg = Vegetation, 1 = Wood grassland, 2 = Riverine forest, 3 = Thicket with scattered bushes, REP = replication, N+CO = NG2G traps baited with different combinations of acetone, cow urine and octenol.

Appendix 6. Analysis of variance for the performance of different unbaited trap designs in catching Tabanidae and Stomoxyinae from different vegetation types of Nechisar National Park.

Veg.	Source of Variation	DF	Tabanidae SS	MS	P	DF	Stomoxyinae SS	MS	P
1	Rep	2	0.0593	0.0297	0.9158	2	0.0498	0.0249	0.7699
	Site (Rep)	6	1.8206	0.3034	0.5186	6	0.0480	0.1747	0.1573
	Day	2	0.0889	0.0444	0.8770	2	0.0230	0.0115	0.8854
	TD	2	0.0439	0.0220	0.9369	2	0.2004	0.1002	0.3690
2	Rep	2	0.4402	0.2201	0.0367	2	0.0974	0.0487	0.1750
	Site (Rep)	6	2.0495	0.3416	0.0018	6	0.2436	0.0406	0.2060
	Day	2	0.7993	0.3996	0.0056	2	0.0689	0.0345	0.2790
	TD	2	0.2687	0.1344	0.1113	2	0.0051	0.0025	0.9026
3	Rep	2	0.8433	0.4217	0.0603	2	1.3355	0.6674	0.0035
	Site (Rep)	6	1.0573	0.1762	0.2664	6	0.5739	0.1762	0.2664
	Day	2	0.1294	0.0647	0.5998	2	0.0975	0.0488	0.5447
	TD	2	0.0146	0.0073	0.9422	2	0.1086	0.0554	0.5099

Veg = Vegetation, 1 = Wood grassland, 2 = Riverine forest, 3 = Thicket with scattered bushes, REP = replication, TD = trap design

Appendix 7. Analysis of variance for the performance of different trap designs baited with acetone in catching Tabanidae and Stomoxyinae from different vegetation types of Nechisar National Park.

Veg.	Source of Variation	Tabanidae DF	SS	MS	P	Stomoxyinae DF	SS	MS	P
1	Rep	2	0.5460	0.2730	0.0050	2	1.4863	0.7432	0.0123
	Site (Rep)	6	1.4621	0.2437	0.0013	6	1.3200	0.2200	0.1688
	Day	2	0.0468	0.0234	0.5233	2	0.1924	0.0962	0.4725
	TD+A	2	0.0791	0.0395	0.3458	2	1.4702	0.7351	0.0128
2	Rep	2	1.0323	0.5161	0.0031	2	0.2969	0.1484	0.1552
	Site (Rep)	6	2.3896	0.3983	0.0014	6	0.2333	0.0389	0.7557
	Day	2	0.1521	0.0761	0.2988	2	0.0316	0.0158	0.7996
	TD+A	2	0.1661	0.0830	0.2700	2	0.2163	0.1081	0.2456
3	Rep	2	0.9493	0.4746	0.0026	2	1.3817	0.6909	0.0049
	Site (Rep)	6	0.5481	0.0914	0.1681	6	0.3508	0.0585	0.6733
	Day	2	0.0028	0.0014	0.9724	2	0.2383	0.1192	0.2856
	TD+A	2	0.2586	0.1293	0.1123	2	0.1638	0.0819	0.4129

Veg = Vegetation, 1 = Wood grassland, 2 = Riverine forest, 3 = Thicket with scattered bushes, REP = replication, TD+A = traps baited with acetone

Appendix 8. Analysis of variance for the performance of different trap designs baited with cow urine in catching Tabanidae and Stomoxyinae from different vegetation types of Nechisar National Park.

Veg.	Source of Variation	Tabanidae DF	SS	MS	P	Stomoxyinae DF	SS	MS	P
1	Rep	2	0.1814	0.0907	0.4783	2	0.3802	0.1901	0.1658
	Site (Rep)	6	0.1020	0.0183	0.9842	6	0.3848	0.0641	0.6606
	Day	2	2.4293	1.2146	0.0017	2	2.3942	1.1971	0.0007
	TD+C	2	0.1735	0.0868	0.4930	2	0.0896	0.0448	0.6268
2	Rep	2	0.1354	0.0677	0.6800	2	0.0470	0.0235	0.2405
	Site (Rep)	6	2.1570	0.3595	0.1178	6	0.2215	0.0369	0.0754
	Day	2	0.1160	0.0580	0.7177	2	0.0067	0.0034	0.8007
	TD+C	2	0.3702	0.1851	0.3651	2	0.0269	0.0134	0.4276
3	Rep	2	0.4946	0.2473	0.0017	2	0.7286	0.3643	0.0208
	Site (Rep)	6	0.4344	0.0724	0.0409	6	0.2558	0.0426	0.7222
	Day	2	0.2930	0.1465	0.0122	2	0.2020	0.1010	0.2713
	TD+C	2	0.0150	0.0075	0.7352	2	0.5868	0.2934	0.0381

Veg= Vegetation, 1= Wood grassland, 2= Riverine forest, 3= Thicket with scattered bushes, REP= replication, TD+C= traps baited with cow urine

Appendix 9. Analysis of variance for the performance of different trap designs baited with octenol in catching Tabanidae and Stomoxyinae from different vegetation types of Nechisar National Park.

Veg.	Source of Variation	Tabanidae DF	SS	MS	P	Stomoxyinae DF	SS	MS	P
1	Rep	2	0.2498	0.1249	0.0910	2	0.4043	0.2022	0.1236
	Site (Rep)	6	1.4268	0.2378	0.0043	6	1.0639	0.1773	0.1134
	Day	2	0.1818	0.0909	0.1617	2	0.1820	0.0910	0.3610
	TD+O	2	0.1812	0.0906	0.1627	2	0.7127	0.3564	0.0351
2	Rep	2	0.8256	0.4128	0.0001	2	0.4473	0.2237	0.0650
	Site (Rep)	6	0.6746	0.1124	0.0014	6	0.2714	0.0452	0.6713
	Day	2	0.2150	0.1075	0.0095	2	0.0462	0.0231	0.7136
	TD+O	2	0.0452	0.0226	0.2810	2	0.0462	0.0231	0.7136
3	Rep	2	1.5715	0.7858	0.0003	2	0.8423	0.4211	0.0319
	Site (Rep)	6	1.6112	0.2685	0.0045	6	0.1087	0.0181	0.9741
	Day	2	0.0038	0.0019	0.9622	2	0.0195	0.0097	0.9029
	TD+O	2	0.0384	0.0192	0.6867	2	0.8885	0.4442	0.0275

Veg = Vegetation, 1 = Wood grassland, 2 = Riverine forest, 3 = Thicket with scattered bushes, REP = replication, TD+O = traps baited with octenol

Appendix 10. Analysis of variance for the performance of NG2G traps baited with different combinations of odour baits in catching Tabanidae and Stomoxyinae from different vegetation types of Nechisar National Park.

Veg.	Source of Variation	Tabanidae DF	SS	MS	P	Stomoxyinae DF	SS	MS	P
1	Rep	2	1.5276	0.7638	0.0001	2	0.2968	0.1484	0.0084
	Site (Rep)	9	1.8412	0.2046	0.0002	9	2.2779	0.2531	0.0001
	Day	3	0.7259	0.2420	0.0015	3	0.4636	0.1545	0.0028
	TD+CO	3	2.4286	0.8095	0.0001	3	0.8176	0.2725	0.0001
2	Rep	2	1.4317	0.7159	0.0001	2	1.7442	0.8721	0.0001
	Site (Rep)	9	1.3324	0.1480	0.0047	9	0.9046	0.1005	0.0366
	Day	3	0.0877	0.0292	0.5665	3	0.1975	0.0659	0.2204
	N+CO	3	1.9962	0.6654	0.0001	3	0.0437	0.0146	0.7937
3	Rep	2	0.4339	0.2170	0.0534	2	1.8821	0.9419	0.0001
	Site (Rep)	9	1.6141	0.1793	0.0211	9	1.0508	0.1168	0.1781
	Day	3	0.4212	0.1404	0.1217	3	1.1466	0.3822	0.0061
	N+CO	3	1.0416	0.3472	0.0054	3	0.5828	0.1943	0.0729

Veg =Vegetation, 1 = Wood grassland, 2 = Riverine forest, 3 = Thicket with scattered bushes, REP = replication, N+CO = NG2G traps baited with different combinations of acetone, cow urine and octenol.