Chapter one

Introduction

Heamatophagous *Diptera* especially the horse flies (tabanids) of the Family *Tabanidae* have public health and high economic impacts because of their role as vector of diseases of humans, farm animals and wild life (foil, 1989). The disease agents they transmitted include viruses, bacteria, protozoa, flat worms and round worms. Although horse flies are important vectors of diseases yet their bites are considered the most serious menace; biting and swarm of such flies around animals in pastures disturb animals grazing and impairment cultivation alike.

In the Sudan, in particular, tabanid flies are of tremendous significant negative effects on the economy and the people lifestyle (Karib, 1951; Hallet, 1983-1984; Rahman, 1997). The insects dictated that over 80% of the Sudanese domestic livestock is to be kept under transhumant system of herd management; future economic development entails settlement of such pastoralists. Attack of these insects in the western region of the country stated the annual northerly migration of the livestock during the rainy season from the dry-season grazing to the relatively tabanid-free grazing pastures (Mohamed-Ahmed *et al*., 1993). While in the southern region along River White Nile banks the tabanids limited the diurnal grazing during dry-season. Hence livestock are enforced to problematic nocturnal grazing which rendering the animals to predation and robbery. During the rains livestock are entirely denied pastures close to the rivers. Moreover the bites of horse flies drive away most wild life to the Goaz area where they have unfortunately, been hunted locally to the point of extinction.

In urban areas, horse flies have established in high density in manmade habitats such as irrigated schemes, sewage canals and farms transmitted mechanically pathogen-trypanosomes of livestock where up to 40% infection rate was scored (Karib 1961; Musa *et al.*, 1990; Abdulla *et al.*, 2005).

Control of horse flies is essential but it is difficult, rather impossible or expensive. Fortunately parallel with recent tsetse flies control trials there seems still choice for control of horse flies using killing gadgets in combination with attractive odour (Kcmar *et al*., 2005). The current study is expected to contribute to our knowledge of species diversity and responses of horse flies to unbaited and baited traps in Blue Nile and Sennar States.

1.1- Overall objective:

Contribute to the development of simple technology for sustainable control of the horse flies associated with humans and domestic animals. This will have imperative conspicuous countrywide impact on the rural and pastoralist economies with subsequent enhance of living standard.

1.2- Specific objectives:

- To select the simplest and most effective insect trap design for horse flies with out and odour attractants.

- To study responses of the target flies as elicited by trap catch size to traps baited with both fresh and fermented urines of cattle, camel, goat, sheep and equines.

- To clarify species diversity and distribution of horse flies in the study area.

Chapter two

Literature review

2.1-Tabanidae (Horse fly):

Tabanidae are dipteran insects commonly known as horse flies or with other names such as breeze flies or deer flies. They vary in size, color pattern, wing and body length that ranges from 5 to 25mm, with large eyes in male occupy the entre head (holoptic) and in female separated by narrow front (dichoptic); the eye coloration varies between species. The wing venation places *Tabanidae* among primitive families of *Diptera*. The antennal structure and the three well developed pads of the feet place the horse flies among *Brachycera* and excluded it from *Nematocera*.

The tabanids are the only *Brachycera* which suck blood (Oldroyd, 1954; Muirhead-Thompson, 1991); the female alone are blood sucker, the males living chiefly on plant juices. They are mainly animals' pests, but many species attack man also inflicting painful bites. They are implicated in the spread of certain diseases of man and animals.

2.2- Classification:

The old classification of *Tabanidae* has been replaced by one based primarily on the genitalia of both sexes (Oldoryd, 1952 and 1957). On a worldwide scale, they are well over four thousand known species of Tabanidae in at least 137 genera (foil, 1989), but only few attract attention.

In the Sudan Lewis (1953) reported seventy species of tabanids, horse flies, locally named Surreta, later on Yagi (1968) added four more species to the Lewis ones. But subsequent to the recent separation and apart from the South Sudan there are only about 24 species occur in the country; belong to three subfamilies of *Tabaninae*, *Pangoniinae* and *Chrysopinae* included into six genera of *Tabanus*, *Atylotus*, *Philoliche*, *Ancala*, *Chrysops*, and *Haematopota*; out of which only *Tabanus sufis, T. taeniola, T. gratus, T. biguttatus, T. par, Atylotus agrestis, A. fuscipes*, *Ancala Africana* and *Philoliche magretti* have received great attention, probably because of their role in disease transmission.

The modern classification is as follows:

Kingdom	*Animalia*
Phylum	*Arthropoda*
Subphylum	*Hexapoda*
Class	*Insecta*
Subclass	*Pterygota*
Infraclass	*Neoptera*
Division	*Endopterygota*
Order	*Diptera*
Suborder	*Brachycera*
Infraorder	*Tabanomorpha*
Super family	*Tabanoidea*
Family	*Tabanidae*

2.3- Distribution of tabanid flies:

Tabanids flies occurring in temperate and tropical regions worldwide found in almost every habitat, from mangroves and beaches to the snow line, and from the extreme deserts to the tropical forests; however they are not accounted in Hawaii, Greenland, and Iceland. Most tabanids have a specific habitat preference, with the exception of a few species with large distribution. Tabanids are global flies yet the aspect of their biology has been poorly studied (Fairchild, 1981).

Balffour (1906), Surcouf (1907), Austen (1909), Surcouf and Ricardo (1909), Krober (1925 and 1927) and much later Oldoryd (1952 and 1957) stated in general terms about Tabanidae and their effect on man and animals in the Ethiopian region.

Lewis (1953) reviewed the first comprehensive review of Tabanidae of the Sudan; gave description of their distribution, biology and ecology. Most of

Tabanus and *Atylotus* species are widely distributed in different types of vegetation zones in the country seem up to date to have the same distribution (Lewis, 1953); *Ancala* species are riverine; *Philoliche* species are exist in the relatively dry central Sudan; the species of *Chrysops*, and *Haematopota* are almost confined to southern Sudan.

Since then only some studies were conducted to assess abundance and distribution of horse flies species in the Sudan; Yagi (1968) and Abdel Razig and Yagi (1975) demonstrated Tabanidae of Kordofan Province; Yagi and Abdel Razig (1972) and Hall *et al*., (1984) described Tahanidae of Southern Darfur Province; Lewis (1953) illustrated the present of seven species of *A. agrestis* and *A. fuscipes*, *T. sufis*, *T. taeniola*, *T. gratus*, *An. africana* and *Ph. magrettii* within the boundaries of Khartoum State, however, in recent times only three species of *A. agrestis*, *T. sufis* and *T. taeniola* were captured in Khartoum State (Sawsan, 1997; Mohamed-Ahrned *et al*., 2007).

2.4- Flight and seasonal abundance of tabanids:

Tabanids species vary both in their potential as vector of diseases or to cause annoyance to man and animals (McClain *et al*., 1975; Foil 1989). Information regarding seasonal abundance patterns of the target tabanids allows recognition of periods when these insects create the greatest stress, and when steps to minimize their impact are sensible. The general seasonal abundance patterns and the importance of meteorological factors for the beginning of flight activity of tabanids species have been investigated and described worldwide and in the Sudan (Miller, 1951; Pechuman *et al*., 1961; Hanec and Bracken, 1964; Yagi and Abdel Razig, 1972; Abdel Karirn, 1980; Hall *et al*., 1984; Ralley, 1986; Sawsan, 1997; Krernar, 2005; Mohamed-Ahmed *et al*., 2007; Faiza,).

The majority of the horse flies in most of the Sudan regions are abundant during the rainy season which occurs from June to October (Yagi and Abdel Razig, 1972; Abdel Karirn, 1980; Hall *et al*., 1984; Sawsan, 1997). However, two flight peaks for horse flies in Khartoum (Mohamed-Ahmed *et al*., 2007; Faiza,) were observed; a higher one occur at the end of the cool-dry and the beginning of the hot-dry season from March to April-May; and a smaller one at the end of the rainy and the beginning of cool-dry season from September to November.

2.5- Diurnal activity patterns

Nearly all females of tabanids species seek blood only during the daylight hours but not at a constant level and dramatically differ in the level to which they are active throughout the day (Hollander and Wright, 1980). The daily patterns of host-seeking activity; the morning onsets of flight activity and cessation of activity in the evening; by female tabanids of several species were observed in the field (Dale and Axtell, 1975; Ruth *et al*., 2002; Ruth *et al*., 2004; Gabriel *et al.*, 2008) and were usually related to simultaneous changes in environmental conditions including saturation deficit, temperature, light intensity and wind speed (Mc Elligott and Galloway, 1991; Faiza).

In the Sudan irrespective of species or season tabanids have roughly bimodal diurnal activity peaks, one in the morning between 09:00 and 12:00 hours and another in the afternoon between 14:00 and 18:00 hours (Sawsan, 1997; Mohamed-Ahmed *et al*., 2007; Faiza).

2.6- Host preference:

The extent to which different hosts are used depends upon host behavior and opportunities for contact. Mammalian host preference in particular cattle are shown by majority of tabanids species (Hall *et al*., 1984; Abdel Karim and Benjamin, 1989) whereas other infest accessible host. This is important in connection with diseases transmission. Mammalian blood is the common protein source for tabanids nonetheless there are some observations of attacks on reptiles and birds (Bennett, 1960; Philip, 1986; Henriques *et al*., 2000). Males are frequently and females are sometimes feed on flowers (Lewis, 1953).

Gorayeb (1985) showed that different tabanid species feed on different areas of the host's body, at different times during the day and in different periods of the year, a strategy to avoid competition.

2.7- Economic important of Tabanids:

Horse flies are haernatophagous insects of economic importance for both man and animals (Coscarn and Gonzalez 1989); they harm their host by direct or indirect injuries. World-wide tabanids are ranked among the major livestock pests but the magnitude of species varies temporally and geographically.

2.7.1-Direct effects of tabanids attack:

Tabanids with their painful bit causing great annoyance, local reactions include dermal nodules, blood loss due to oozing and daily weight gain decline. It was estimated that 25 to 30 *Tabanus* species feeding on a host for 6 hours would take at least 100 ml of blood (Webb and Wells, 1924). More recent studies have established that 66-90 horse flies per day can reduce daily weight gain by 0.1 kg per yearling heifer, and populations feeding on cattle can far exceed this burden in many regions. US$ 30-40 million annually were attributed to reduction in weight gains due to tabanid attacks in the USA (Anon, 1979). The bite wounds may serve as secondary infection and invention of myiasis producing flies (Foil and Hogsette, 1994). Tabanids were considered to be the major factor in causing seasonal migration of domestic and wild-animals (Lewis, 1953: Yagi and Abdel Razig, 1972).

2.7.2- Disease transmission (indirect effects of tabanids attack):

Foil (1989) has discussed the entire spectrum of disease transmission of infestation by tabanids. Horse flies are biological and mechanical vectors of various animal infectious disease agents (Krinsky, 1976) among which trypanosomosis and anaplasmosis stand out.

2.7.2.1- Trypanosomosis transmission:

Tsetse flies or *Glossina* species are the biological vectors and clearly play the most important role in the transmission of the most African livestock pathogenic trypanosomes of *Trypanosoma congolense*, *T. vivax*, *T. brucei* (Hoare, 1972). However these parasites may also be mechanically transmitted by tsetse and other biting insects (Moloo *et al*., 2000), yet critical evidently epidemiological confirmation of this transmission is not clear.

There is evidence that mechanical transmission for *T. vivax* occurs and persist in areas devoid of the biological vector is known in Latin America and in Africa (Roeder *et al*., 1984; Cuisance, 1994; Cherenet *et al*., 2004; Desquesnes, 2004; Bouycr *et al*., 2005).

In the Sudan, El Karib (1961) considered animal trypanosomosis to be mainly a problem of mechanical transmission via biting flies particularly those belong to the family Tabanidae. Numerous studies were conducted on tabanids targeting their affiliation to animal trypanosomosis in the tsetse free areas. The obtained results indicated that there is a strong correlation; the high density of biting flies' populations the high disease prevalence (Yagi and Abdel Razig, 1972; Hall *et al*., 1984; Suliman, 1992; Rahrnan *et al*., 1997; Rahman, 2005).

Studies of Mihok *et al*., (1995) and Sumba *et al*., (1998) indicated that *T. brucei* and *T. congolense* can be mechanically transmitted; however, epidemiological evidence of this transmission is not clear.

Trypanosoma evansi the causative agent of Surra disease is a species of the subgenus *Trypanozoon*, belongs to the Salivaria section of *T. brucei* group, does not undergo a cycle transmission in tsetse flies. The disease is with wider geographical distribution and mammalian host range than any other pathogenic species of *Trypanosoma*. Studies of the epidemiology and impact of the disease showed the through mechanical transmission *T. evansi* spread outside the tsetse belt in Africa and exported similarly into Latin America and Asia where it infected new hosts and reservoirs. Although the disease is often endemic outbreaks in African camels (Diall *et al*., 1993; Dia, *et al*., 1997) and in Asian cattle, buffaloes, horses and pigs (Tuntasuvan *et al.,* 1995) and in buffaloes of Latin America (Garcia *et al*., 2005) have been reported.

The distribution of the Surra disease in the Sudan is intimately coincide to that of tabanids flies (Mahmoud and Osman, 1979) existing mainly in arid and semi arid areas north of latitudes 12°N. Surra disease is endemic in all camel rearing areas of the country has been recognized as an important disease of livestock since the last century threat the camel industry (Rae *et al*., 1989; Abdel Rahman *et al*., 2007). Other animals such as donkeys and cattle are usually found with camels in pasture although their contribution to the epidemiology of camel trypanosomosis has not yet been evaluated (Ismail *et al*., 2007).

2.7.2.2- Anaplasmosis transmission:

Anaplasmosis is a non-contagious infectious disease of ruminants and man occurs in many areas of the world. Bacteria *Anaplasma* causative organism of Anaplasmosis are cyclic transmitted by various hard tick species and acyclic transmitted by haematophagous arthropods (Rymaszewska and Grenda, 2008; Tembue *et al*., 2011).

Hawkins *et al*., (1982) demonstrated that various species groups were remaining able to transmit *Anaplasma marginale* to cattle for at least two hours after an interrupted blood meal. More recently, Hornok *et al*., (2008) provided the molecular evidence for the mechanical vector role of 316 haernatophagous arthropods including 6 species of tabanid flies in the transmission of *A. marginale* in Hungary.

In the Sudan the tick-borne disease Anaplasmosis representing main constriction that retarded the intensive animal production systems due to the considerable economic losses incurred. Yet there are scanty studies to handle the impact of bovine Anaplasmosis (Mohammed *et. al*., 1998). Occurrence of

A. marginale parasites among dairy farm cattle was observed with high prevalence (Mohammed *et. al.*, 1998; Sulieman, 2004; Adam, 2005). However, other forms of transmission include mechanical means is considered the major route of dissemination (Mohammed *et. al*., 1998)

2.8- Tabanids Control:

Control campaigns for tabanid flies are limited, though are necessary. The control of such flies expensive is either difficult, rather impossible (modification of habitat: destroying breeding sides, draining water bodies) or expensive and polluting (insecticides application; area-wide scale). Nevertheless, many control procedures have been evaluated in attempts to reduce horse fly populations attacking livestock, but few have given a satisfactory reduction of populations.

Insecticide sprays directed into the wooded edges of agricultural areas have provided inconsistent and poor control of horse flies (Howell *et al*., 1949; Hansens, 1981) in USA.

Living-insecticides by mean of spraying animal with residual insecticides have been shown to be relatively effective against horse flies (Bay *et al*., 1976; Harris and Oehler, 1976; Presley and Wright, 1986). Foil *et al*., (1990) reported that, in North America tabanids feeding time on treated cows using fenvalerate spray was reduced. Presley and Wright (1986) tested various insecticide formulations against *Tabanus* species, found that 1.0% permethrin pour-on was the most effective insecticide. Unfortunately, most of the horse fly species prefer to feed on the legs and lower side where insecticides are poorly distributed by pour-on formulations.

Worked on tabanids trapability was established early in order to develop economical simple trap, suitable for consumer use, and with high performance; typically catches more horse flies. Good trap performance for all species is difficult to achieve (Gibson and Torr, 1999). Many trap designs were developed and used, such as Manitoba trap and modified Manitoba-pyramid traps (Thorsteinson *et al*., 1965; Wilson, 1968; Hansens *et al*., 1971), did not adequately protect cattle from tabanids.

In a major trial of box traps to control *Tabanus* species there was a decrease in the nuisance levels of these flies (Wall and Doane, 1980). Large black animals are considered to be most attractive for tabanids; the canopy traps or box traps employ this principle (Foil and Hlogsette 1994). Moreover Watson *et al*., (2006) conducted a study to examine differences between two commercially available horse fly traps, the Epps and the Horse Pal trap. The Horse Pal trap captured significantly more flies than the Epps trap.

The simple and economical Nzi trap was recently described (Mihok, 2002) and designed for equitable efficiency for tsetse, stable flies and tabanids. It has been tested extensively in the tropics, but few studies have been conducted elsewhere.

A study carried out by Mohamed-Ahmed *et al*., (2007) indicated that Nzi trap could be the best trap for monitoring and control of horse flies in the Sudan compared with canopy, NGU2b and biconical traps, because it caught various species in different climates, high numbers of flies entering trap, more economic than other conventional tabanids traps and easy to make. Hence, fortunately parallel with recent tsetse flies control trials there seems still choice for control of horse flies using killing gadgets in combination with attractive odour (Kcmar *et al*., 2005).

Chapter three

3. Materials and Methods

3.1- Study area

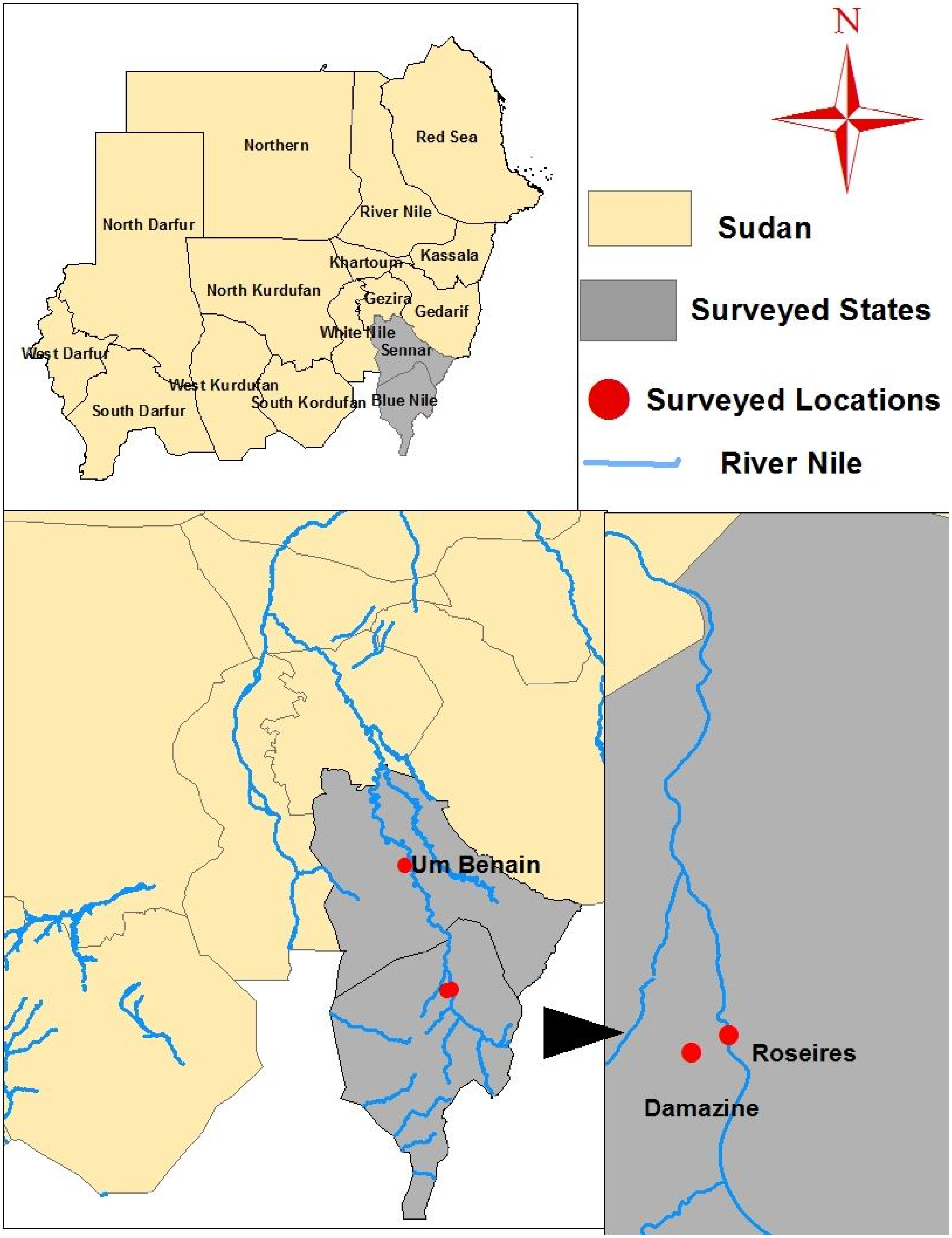
This study was conducted in the Blue Nile region including; Ed Damazein and Er Roseries Localities (Mahalia) in the Blue Nile State; and Umm Banein Locality in the Sennar State, Sudan; the area is well known as Fung area. The area, located in south-eastern part of the Sudan, lies entirely between Latitudes 10° 30´ and 13° 04´ N and Longitudes 33° 67´ and 35° 43´ E, bordering El Jassera State from the North, the Republic of South Sudan from the West and Ethiopia from the East direction.

3.2- Climate:

The climate is characterized by minimal variations in seasonal temperatures. The highest mean maximma occur during April-May just before the rains and range between 40 - 41.9°C, while the mean minima occur during the cool-dry season last November to March range between 16 – 20.8°C. The rains are characterized by a remarkably regular decrease from south to north with total annual means ranging between 200 to 570 mm. The rainy season start early last April in the south and as late as at June in the north part of the region and ending in October. The relative humidity (RH %) range between 37% in the hot dry season and 85% during the rainy season.

3.2.1- Metrological data:

The data provided by the Metrological Unit of Umm Banein Livestock Research Station (ULRS) at Umm Banein Locality, are shown in Table A and Figure A.


N
Red Sea
Northern
North Darfur
River Nile
Khartoum
Kassala
North Kurdufan
Gezira
Gedarif
White Nile
Sennar
West Darfur
West Kurdufan
South Kordufan
Blue Nile
South Darfur
Sudan
Surveyed States
Surveyed Locations
River Nile
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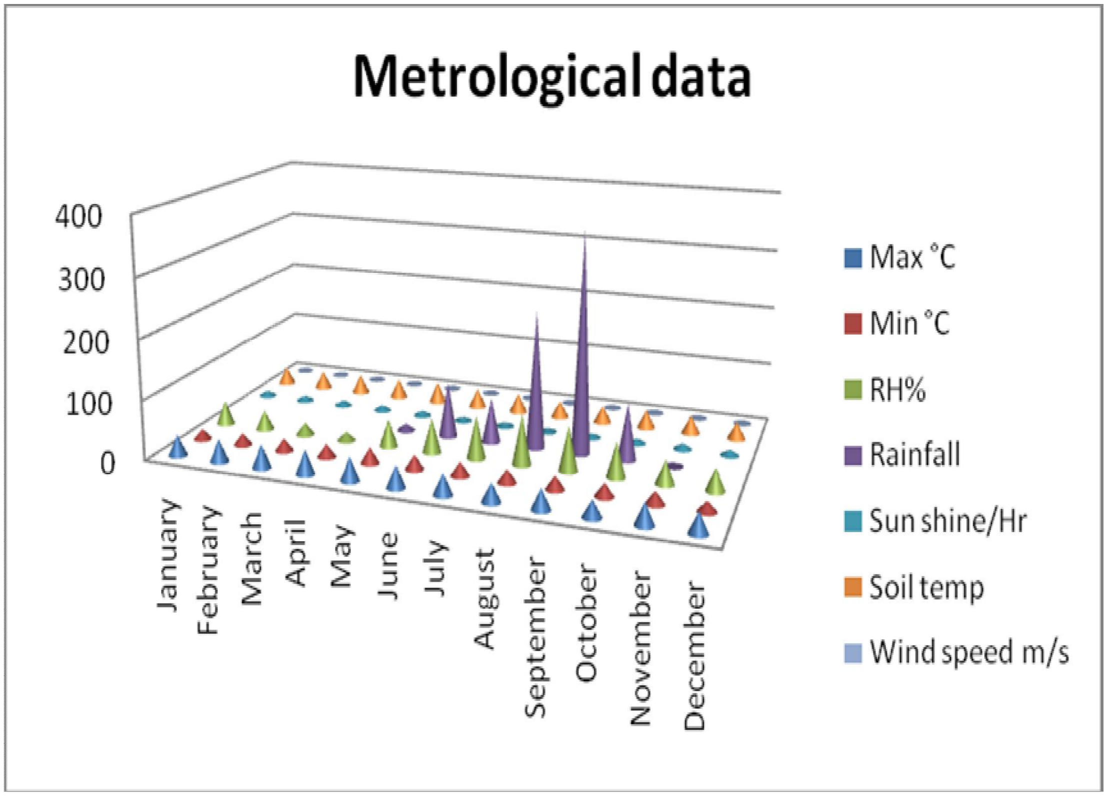
Roseires
Damazine

Table A: Showing the different metrological data of the study area

Month	Max °C	Min °C	RH%	Rainfall	Sun shine/Hr	Soil temp	Wind speed m/s
January	35.2	17.7	41		9.2	29	0.84
February	37.9	20	33		9.3	30.3	0.9
March	40.2	21.4	21		9.3	32.3	0.71
April	41.4	22.4	15		9.8	33.5	0.87
May	40.8	26.8	46	12	9	35.7	0.6
June	38.1	25.6	57	94	7	33.1	0.76
July	35.7	24.2	72	76	6.5	32.9	0.65
August	31.8	22.7	84	230	5	28.4	0.63
September	34.2	22.9	76	369	7.1	29.3	0.41
October	28.1	22.6	60	95	8.3	31.2	0.46
November	37.1	21	41	0.5	10.1	31.4	0.65
December	34.4	17.4	39		9.8	29.2	0.86

Figure A: Representing the different metrological data



3.3- Vegetation covers:

The most dominant feature of the area is River Blue Nile. The study area lies within the Low Rainfall Woodland Savannah on Clay belt, with vast dark cracking clay plains broken in the eastern and southern by high mountainous ranges of the Ethiopian Territory Mountain and Ingassana Hill, respectively, and transected by a vast number of seasonal watercourses. Several seasonal swamps or basins (Mayat) flooded from the River Blue Nile, watercourses and rain are widely disseminated in the area.

The vegetation cover is alternating with grass areas and interrupted by several towns, villages and hamlets. The grass land is utilized by inhabitants for subsistence cultivation plots and for grazing their animals. The grasses occur in separate patches with each patch dominated by single grass. The main grasses are of the *Imperata*, *Panicum* and *Andropogon* species together with *Combretum glutinosum* and various climbers.

The trees on the drier parts in the north and east are nearly all thorn trees of low stature, principally *Acacia mellifera*, *A. seyal* and *Balanites aegyptiaca* with some thorn bushes and shrubs. Broad leaved deciduous trees such as *Ficus religiose*, *Tamarindus indica* and *Azadirachta indica* become predominant in the wetter parts particularly in the south, but there is less as much variety of species and a proportion of thorn trees is usually present. Near the River Blue Nile on silty soils (Azaz) the *Acacia* savannah is locally replaced by non-thorny woodland comprise patches of evergreen trees in which *Combratum* and *Adansonia* species are dominant. Along the Blue Nile bank the forest of *A. nilotica* attain their best development and numerous subsistence irrigated farms for vegetable and fruit products are present.

The wooded parts, basins, watercourses and irrigation canals provide favourable microclimatic conditions (resting and reproduction sites) for the horse flies while the cleared parts, grass-land, provides feeding sites allow an abundance of hosts.

3.4- Horse-flies hosts:

The area is the most important area from a grazing point of view covered by several migrations of the tribes who their animals live on free grazing.

The area is famous for its sheep of Watish breed and the indigenous productive dairy cattle of Kennana and Rufaa breeds. Other domestic animals present including goats, equine, camels, dogs, domestic cats and rarely domestic pigs (Kadrook). Over 90% of the livestock is kept under transhumant system of herd management.

3.5-Traps

Three trap designs were used namely Nzi (Mihok, 2002), Vavoua (Laveissiére and Grébaut, 1990) and White Biconical (Challier *et al*., 1977). All traps were locally made from Sudanese black cotton cloth, imported blue phthalogen cotton and white Terylene mosquito netting. The white netting and blue phthalogen cotton were imported from Kenya (United Textiles Industries, Nairobi, Kenya) as recommended by scientists in the International Center of Insect Physiology and Ecology (ICIPE).

3.6- Attractants:

A total of 24 substances were tested during this study consist of fresh and ferment urine collected from both male and females of goat, sheep, camel, donkey, horse and cattle; water was used as control.

Urine from male-animal was collected by fitting open sterile plastic container secured ventrally at the urethral opening using clean plastic ropes; urine was collected as it was passed. Urine from female was collected as soon as it started to urinate by an observer held a sterilized plastic container.

Each urine sample was divided into two parts; one part was kept frozen at -20°C until use and termed fresh-urine; the other part was kept at room temperature (25 - 40°C) for at least three weeks and left to aged or fermented and termed fermented or ageing-urine.

A plastic container (6cm diameter: 11cm high) was used to dispense water, the fresh and aged urine. It was placed at the base of the Nzi trap and changed daily.

3.7- Horse flies density and occurrence:

The unbaited and baited-traps were set 200 m apart to avoid intervention between treatments. The captured flies were collected daily at 17:00 pm sorted, identified, calculated and recorded as fly apparent density (fly mean $\pm$ SE/trap/day) based on species diversity, location, habitat, season and trap design.

3.8- Trap relative efficiency:

The trap apparent efficacy against the horse flies was estimated by randomized Latin Square design where the number of site and days was equal to the number of the traps tested (Perry *et al*., 1980).

3.8.1- Comparison between the Nzi and Biconical traps:

For first course, a preliminary trial was conducted to compare the apparent efficiency of the Nzi and Biconical trap. Since the area has been reported to contain different species of the horse flies and different traps have different catch composition and performance hence both traps were tested to select the best.

The traps were tested in Ed Damazein and Er Roseries Localities at the *Acacia* woodland forest area and grazing area at arid flat and raised ground. Randomized 2X2 Latin Square Design was executed in each habitat and the experiment was replicated twice. Traps were erected 200m apart and alternated between sites daily in each replicate of two days. Catches were collected every 24 hours. Traps' stands were appropriately greased to prevent ants and lizards from raiding the yield.

3.8.2- Comparison between the Nzi, Biconical and Vavoua traps:

The preliminary experiment has shown that the Nzi is superior to the Biconical, yet the two traps have different catch composition. Hence biconical series trap namely Vavoua was compared with the both traps for its efficiency in capture horse flies. The objective was to find out the simplest, cheapest and effective trap design against the local species.

Nine traps consisting of Nzi , Biconical and Vavoua traps were used. Randomized 3X3 Latin square designs incorporating the effects of day, site and treatment were used. The experiment was replicated thrice and conducted in Er Roseries Locality at three different micro-habitat types including *Acacia* woodland forest and grazing area at arid flat and raised ground. In each habitat traps were erected and catch flies were treated as described above (3.7.1).

3.8.3- Comparison between the Nzi, Biconical and modified Biconical traps:

The preliminary experiment has shown that the Nzi is superior to the Biconical. In view of the fact that the two traps have different catch composition; a Turquoise Biconical trap was compared for its efficiency in capture horse flies. The objective was to find out the effective trap design against the local species.

Nine traps consisting of Nzi, White Blue Biconical and Turquoise Biconical traps were used. Randomized 3X3 Latin square designs incorporating the effects of day, site and treatment were used. The experiment was replicated thrice and carried out in Umm Banein Locality at three different micro-habitat types including crop growing area, riverine-farm and *Acacia* woodland forest. In each habitat traps were erected and catch flies were treated as described in the preliminary experiment above (3.7.1).

3.8.4- Comparison between three modifications of the Nzi trap:

Since the Nzi trap (Mihok, 2002) has proved to be highly effective against the horse flies, an experiment was conducted to further improve the efficiency of this design using three simple modifications of the trap. The standard Nzi trap is consisted of three blue panels a horizontal front and vertical wings shelf. Modification 1 (M1) has a black horizontal front; modification 2 (M2) has black vertical wings shelf; modification 3 (M3) the three panels, the horizontal front and the vertical wings shelf, were consisted of black polyester; the body of the trap was in the shape of an equilateral triangle 90cm along each site.

The experimental design was 4x4 randomized Latin Square Design replicated twice in Ed Damazein Locality at the woodland forest. Trap sitting, measures and collection of capture flies were similar to those in the above-mentioned experiment (3.7.1).

3.8.5- Comparison between unbaited and baited Nzi trap:

Since the tested different Nzi trap designs have proved to be highly effective against the horse flies yet with no significant differences, an experiment was conducted to enhance the efficiency of the standard Nzi design using attractant of different causes.

The fresh and ferment urine of male and females of small ruminant (goat, sheep), large ruminant (camel, cattle) or equines (donkey, horse) were tested independently; water was used as control. The 5x5 Randomized Latin Square experimental design replicated twice was conducted in Umm Banein Locality at the *Acacia* woodland forest and the raised ground. Trap sitting and precautions and collection were similar to those in the above-mentioned experiment (3.7.1).

3.9-Data analysis:

Means of the numerical data were compared by the paired or independent Student t-test using a computerized programme in a desktop personal computer, values were considered significant at the probability $P = 0.05$ or less.

For Latin Square the pooled catches (n) were compared by analysis of variance (ANOVA) after transformation of catches to $\log_{10}(n + 1)$. Significant differences between trap catches were detected by the Student-Newman-Keuls (SNK) (*P* = 0.05**). C**atch indices for each trap were calculated as back-transformed mean catch for the test trap divided by the back-transformed mean catch of the Nzi trap. Back-transformed means are presented.

Chapter four

4. Results

4.1- Surveys of biting flies:

Using unbaited Nzi, Biconical and Vavoua traps entomological surveys were undertaken to cover the main vegetations habitats such as farm hedges, *Acacia* woodland, flat and raised grazing lands. The selected locations were investigated for biting flies prevalence during the rainy, hot-dry or cool-dry season from July 2012 to April 2014 using as possible the same trap sites. The traps were set 200 m apart to avoid intervention between treatments. Tabanids altogether with Stomoxyes and Muscids species were trapped yet only tabanid flies were identified.

4.1.1- Horse flies species diversity and occurrence:

The obtained results are summarized in Table 1. During the course of the study period 1517 tabanid flies were collected from Ed Damazein Locality comprise of *Atylotus agrestis* (1415; 93.28%), *Tabanus taeniola* (92; 6.06%), *T. par* (2; 0.13%), *T. sufis* (1; 0.07%) *T. biguttatus* (1; 0.07%), *Philoliche magretti* (4; 0.26%) and *Haematopota* species (2; 0.13%); 1522 tabanids from Er Roseries Locality including *A. agrestis* (1272; 83.57%), *A. fuscipes* (99; 6.50%), *T. taeniola* (39; 2.56%), *T. biguttatus* (7; 0.46%), *T. sufis* (5; 0.34%), *Ph. magretti* (96; 6.31%) and *Haematopota* species (4; 0.26%); only 325 tabanids were captured from Umm Banein Locality involving *A. agrestis* (261; 80.31%), *T. sufis* (51; 15.69%) and *T. taeniola* (13; 4.13%).

Atylotus agrestis and *T. taeniola* were encountered roaming in the three different micro-habitats investigated in Ed Damazein and Er Roseries Locality; the *Acacia* woodland forest; and the grazing area at arid flat or raised ground. Whereas *T. par* and *T. sufis* were trapped in the *Acacia* woodland forest; *A. fuscipes*, *T. biguttatus*, *Ph. magretti* and *Haematopota* species were caught in the grazing raised ground in the east.

In Umm Banein Locality *A. agrestis*, *T. taeniola* and *T. sufis* were captured in the three micro-habitats investigated including crop growing area, riverine-farm and *Acacia* woodland forest.

4.1.2- The horse fly species apparent density per trap per region:

The apparent density (fly mean $\pm$ SE/trap/day) of the captured flies fly based on the region and trap design were assessed, the obtain results are summarized in Table (2 and 3).

In general in the Blue Nile region and Sennar region the Nzi trap was always superior to the Biconicals and Vavoua traps trapped significant ($p < 0.5$) more flies including *Ph. magretti*; nevertheless the later traps caught more *T. biguttatus* than the Nzi one.

As far as to our knowledge this is the first ever record of trapping *Ph. magretti* and *T. biguttatus* with unbaited cloth-traps.

4.1.3- Seasonal abundance of the horse fly species:

The predominant species was *A. agrestis*; together with *T. taeniola* were encountered with different proportion throughout the three seasons. The *A. fuscipes*, *T. biguttatus* and *Ph. magretti* were caught during the rainy and cool-dry seasons; *T. sufis* was trapped in both the cool and hot-dry seasons; while *T. par* and *Haematopota* species were only captured in the rainy and cool-dry season, respectively (Table 4).

The general seasonal abundance pattern of the trapped horse flies has been investigated using Nzi tap. As shown in Table 5, the majority of the horse flies are abundant during the rainy season (July-October).

The *A. agrestis* showed bimodal curve of flight; two peaks a smaller one signaling the start of the rain and a higher one at the end of the rainy season and the beginning of the cool-dry season (October- November). At the end of the rainy season and the beginning of the cool-dry season (October- November) *A.*

fuscipes, *Tabanus taeniola, T. sufis, T. biguttatus, T. par, Ph. magretti* and *Haematopota* species showed one hump flight peak (Figure 1, 2, 3).

Table 1: Shows the prevalence of the different tabanids species caught in the study area.

Fly species	**Ed Damazein**	**Er Roseries**	**Umm Bbanein**
Atylotus agrestis	93.28%	83.57%	80.31%
A. fuscipes	-	6.50%	-
Tabanus taeniola	6.06%	2.56%	4.00%
T. sufis	0.07%	0.34%	15.69%
T. biguttatus	0.07%	0.46%	-
T. par	0.13%	-	-
Philoliche magretti	0.26%	6.31%	-
***Haematopota* species**	0.13%	0.26%	-

Table 2

Fly species	**Nzi trap**	**Biconical trap**	**Vavoua trap**
A. agrestis	73.1 ± 34.2	20.2 ± 6.7	4.8 ± 1.9
A. fuscipes	8.0 ± 4.1	2.2 ± 0.8	0.2 ± 0.1
T. taeniola	3.2 ± 1.9	0.3 ± 0.3	00
T. sufis	0.3 ± 0.2	0.1 ± 0.1	0.1 ± 0.1
T. biguttatus	0.1 ± 0.1	0.2 ± 0.1	0.2 ± 0.1
Ph. magretti	8.1 ± 4.3	0.1 ± 0.1	0.1 ± 0.1
Haematopota	0.2 ± 0.1	00	0.2 ± 0.2

Table 3

Fly species	**Nzi**	**Blue Biconical**	**Turquoise Biconical**
A. agrestis	13.1 ± 2.4	1.7 ± 0.3	2.6 ± 0.8
T. sufis	2.7 ± 0.5	0.3 ± 0.2	0.5 ± 0.3
T. taeniola	0.9 ± 0.5	-	-

Table 4: Shows the prevalence of tabanids species caught during different season, in the study area.

Fly species	**Rainy season**	**cool-dry season**	**Hot-dry season**
Atylotus agrestis	94.87%	84.72%	87.60%
A. fuscipes	0.61%	4.63%	0.00%
Tabanus taeniola	0.98%	6.06%	2.52%
T. sufis	0.00%	0.30%	9.88%
T. biguttatus	0.24%	0.30%	0.00%
T. par	0.24%	0.00%	0.00%
Philoliche magretti	3.05%	3.69%	0.00%
***Haematopota* species**	0.00%	0.30%	0.00%

Table 5: Shows the seasonal abundance of tabanids species caught in the study area.

Fly species	April	July	August	October	November	February
A. agrestis	261	579	198	883	836	191
A. fuscipes	0	0	5	94	0	0
T. taeniola	13	1	7	32	91	0
T. sufis	51	0	0	5	1	0
T. biguttatus	0	0	2	5	1	0
T. par	0	2	0	0	0	0
Ph. magretti	0	4	21	75	0	0
Haematopota	0	0	0	4	2	0
Pool tabanids	**325**	**586**	**233**	**1098**	**931**	**191**

Figure 1: Nzi trap monthly catches of *Atylotus agrestis* and *A. fuscipes* in the Blue Nile area.

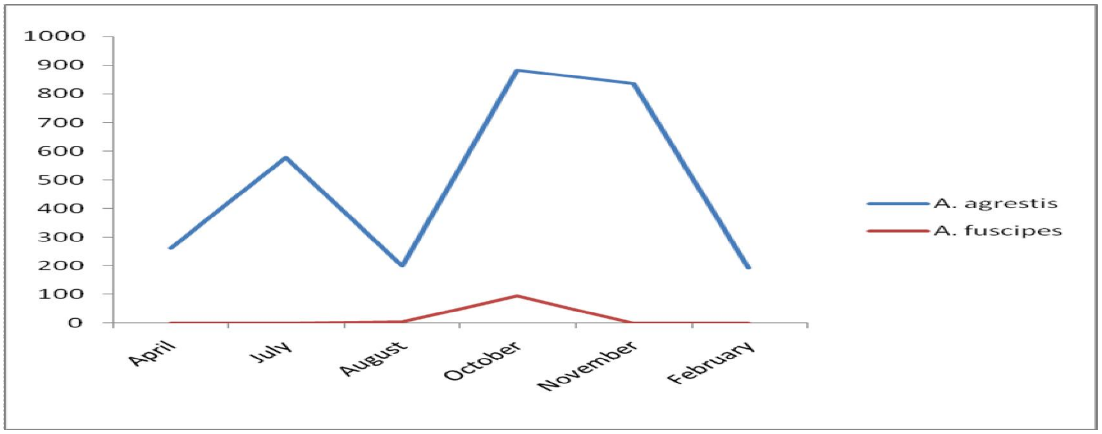


Figure 2: Nzi trap monthly catches of *Tabanus taeniola*, *T. sufis*, *T. biguttatus* and *T. par*, in the Blue Nile area.

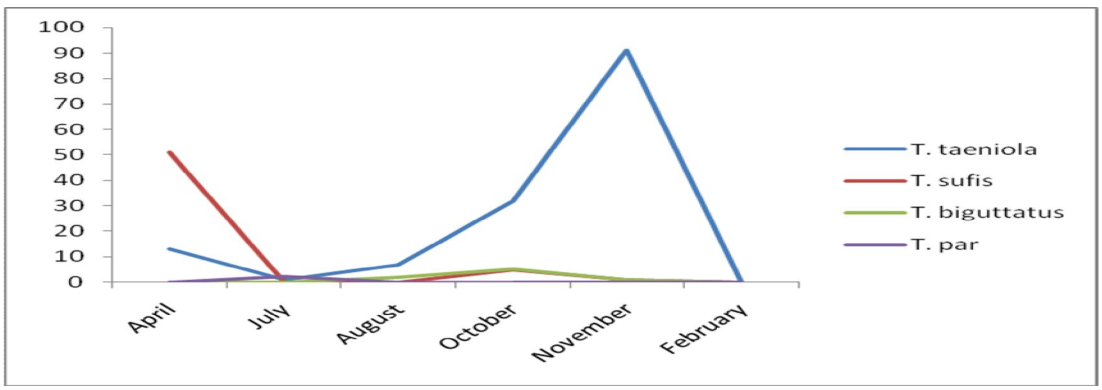
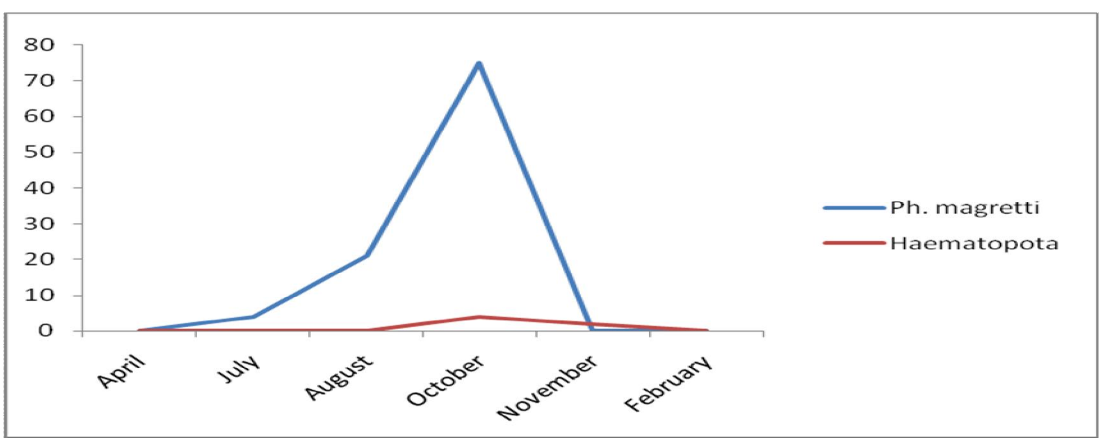


Figure 3: Nzi trap monthly catches of *Philoliche magretti* and *Haematopota* species in the Blue Nile area.



4.1.4- Trap efficiency:

In order to realize the best trap for the local horse fly population the Nzi, baited Nzi, modified Nzi, Blue-Biconical, Turquoise Biconical, and Vavoua traps were investigated.

4.1.4.1- Comparisons between the Nzi and the Blue Biconical trap

In an initial test the performance of Nzi and Blue Biconucal traps for trapping the horse flies was tested. The two traps were alternated with each other for two days in each of the three dominant vegetation types in Ed Damazein and Er Roseries Localities. Many species of horse flies including *A. agrestis*, *A. fuscipes*, *T. taeniola*, *T. biguttatus*, *T. par* and *Ph. magretti* were caught during the present test. Regardless of type of vegetation the Nzi trap caught up to 1.5 and 4.5 times significant more horse flies than the Biconical trap in Ed Damazein and Er Roseries Localities, respectively. These results confirmed the confidence that the Nzi trap was significantly more effective against the species of the horse flies than the Biconical trap (P<0.001; Table $6_{\text{a and b}}$).

4.1.4.2- Comparisons between the Nzi, Blue Biconical, and Vavoua traps:

The Vavoua and Nzi traps are uncomplicated and inexpensive compared with the original Biconical trap design. Hence if the Vavoua is statistically more than or as efficient as the original Biconical trap it must be adopted for sampling and controlling of the horse flies. The high F ratios of the treatment in Ed Damazein and Er Roseries region (Table $7_{\text{a and b}}$) illustrated that the Nzi trap is the highly significant source of variation.

The short test significant (SSR) indicated that the Nzi caught significantly more flies than the Biconical and Vavoua traps and the Biconical trap also trapped significantly more flies than the Vavoua one.

4.1.4.3- Comparisons between the Nzi, Blue Biconical, and Turquoise Biconical traps:

Unfortunately, the obtained result (4.1.3.2) demonstrates clearly that the simpler Vavoua trap is significantly ($p < 0.002$) not as efficient as the Nzi and the more complex original Biconical design. In the current experiment the blue colour of the lower cone of the original Biconical design was changed to turquoise colour. Then the Turquoise Biconical was compared with the Nzi and Blue Biconical Trap. The assessment showed (Table 8) that the Nzi trap caught significantly more horse flies than the both Biconical traps. The Biconical trap and its modification were as efficient as each other.

Table 6_a: Back-transformed mean catches and catch indices of pooled horse flies in Ed Damazein Locality using Nzi and Blue Biconical traps.

Trap type	Mean catch	Index	F-ratio
Biconical	12.48	1.0	5.444*
Nzi	18.93	1.5	

* $P < 0.05$

Table 6_b: Back-transformed mean catches and catch indices of pooled horse flies in Er Roseries Locality using Nzi and Blue Biconical traps.

Trap type	Mean catch	Index	F-ratio
Biconical	4.61	1.0	12.179**
Nzi	20.85	4.5	

** $P < 0.002$

Table 7_a: Back-transformed mean catches and catch indices of pooled horse flies in Ed Damazein Locality using Nzi, Blue Biconical and Vavoua traps.

Trap type	Mean catch	Index	F-ratio	SSR
Vavoua (T_1)	4.28	1.0	16.282**	T_3-T_1 = 1.120
Biconical (T_2)	13.78	3.2		T_3-T_2 = 0.507
Nzi (T_3)	56.54	13.2		T_2-T_1 = 0.613

**** P < 0.002**

Table 7_b: Back-transformed mean catches and catch indices of pooled horse flies in Er Roseries Locality using Nzi, Blue Biconical and Vavoua traps.

Trap type	Mean catch	Index	F-ratio	SSR
Vavoua (T_1)	2.05	1.0	13.778**	T_3-T_1 = 1.300
Biconical (T_2)	4.39	2.1		T_3-T_2 = 0.974
Nzi (T_3)	10.38	5.1		T_2-T_1 = 0.330

**** P < 0.002**

Table 8: Back-transformed mean catches and catch indices of pooled horse flies in Umm Bbanein Locality using Nzi, Blue Biconical and Turquoise Biconical traps.

Trap type	Mean catch	Index	F-ratio	SSR
BlueBiconical (T_1)	3.34	1.0	52.021**	T_3-T_1 = 0.815
Turquoise Biconical (T_2)	4.61	1.4		T_3-T_2 = 0.675
Nzi (T_3)	21.83	6.5		T_2-T_1 = 0.140

**** P < 0.002**

4.1.5 Improvement of Nzi trap competence:

Since the above results have revealed that the original Nzi trap (Mihok (2002) is more effective against the horse flies than the Biconical and Vavoua traps. Hence to improve its efficiency the trap was modified or baited with urine.

4.1.5.1- Response of tabanids to three modification models of the Nzi trap:

In present experiment the colour of the vertical wings shelf (Modification 1); the horizontal front (Modification 2); the three panels (Modification 3) were changed into black colour to improve the efficiency of the Nzi trap.

Table 9 shows that M1, M2 and M3, the three modifications of the Nzi trap, caught 2.6, 2.4 and 1.5 times more flies than the original Nzi trap, respectively, yet they were not statistically significantly ($p > 0.5$) better than the original Nzi trap.

4.1.5.2- Response of tabanids to urine-baited Nzi traps:

The pervious test illustrated that modifications of Nzi trap design insignificantly enhanced the performance of the trap. The current experiment is conducted to improve the competence of the original Nzi design using fresh and fermented urine of male and females of small ruminant (goat, sheep), large ruminant (camel, cattle) or equines (donkey, horse) separately.

Volatiles from fresh as well as ageing urine of small ruminant in general depressed the yield (Table $10_{a\text{-}b}$) yet did not significantly affect the Nzi trap catches of tabanids. In contrast volatiles from fresh and ageing urine of large ruminant as well as from equines enhanced the trap catch (Table $10_{c\text{-}d}$ and $10_{e\text{-}f}$) but no significant differences were seen.

The species of tabanid most commonly collected was *Atylotus agrestis* comprised (80.31%) of the total, followed by *Tabanus sufis with* (15.69%) and *T. taeniola* with (4.13%). Also the majority of species was collected in Nzi traps baited with fresh or aged cow or horse-female urine.

Table 9: Back-transformed mean catches and catch indices of pooled horse flies in Ed Damazein Locality using three modifications of the Nzi trap and Nzi traps.

Trap type	Mean catch	Index	F-ratio
Modification 1 (T_1)	16.69	2.6	
Modification 2 (T_2)	13.27	2.4	
Modification 3 (T_3)	8.55	1.5	0.919^{ns}
Nzi trap (T_3)	5.61	1.0	0.599^{ns}

^{ns} ***P* > 0.05**

Table 10_a: Back-transformed mean catches and catch indices of pooled Horse flies in Umm Banein Locality using Nzi trap baited with fresh urine of small ruminant animals.

Odour	Mean catch	Index	F-ratio
Female goat	0.6868	0.81	
Male goat	0.5998	0.63	
Male sheep	0.661	0.75	
Female sheep	0.8541	1.29	2.043^{ns}
Control	0.7598	1.00	3.213*

^{ns} ***P* > 0.05**

Table 10_b: Back-transformed mean catches and catch indices of pooled Horse flies in Umm Banein Locality using Nzi trap baited with fermented urine of small ruminant animals.

Odour	Mean catch	Index	F-ratio
Female goat	0.9912	1.09	
Male goat	0.6433	0.92	
Male sheep	0.881	0.81	
Female sheep	0.911	0.88	2.589^{ns}
Control	.9597	1.00	3.616*

^{ns} *P* > 0.05

Table 10_c: Back-transformed mean catches and catch indices of pooled Horse flies in Umm Banein Locality using Nzi trap baited with fresh urine of large ruminant animals.

Odour	Mean catch	Index	F-ratio
Bull	9.70	1.42	
Cow	10.95	1.59	
Camel	7.88	1.15	
She-camel	5.94	0.87	1.491^{ns}
control	6.86	1.00	4.11^{s}

^{ns} *P* > 0.05

Table 10_d: Back-transformed mean catches and catch indices of pooled Horse flies in Umm Banein Locality using Nzi trap baited with fermented urine of large ruminant.

Odour	Mean catch	Index	F-ratio
Bull	7.83	0.73	
Cow	7.78	0.72	
Camel	8.10	0.76	
She-camel	6.21	0.58	0.173^{ns}
Control	10.74	1.00	0.007^{ns}

^{ns} ***P* > 0.05**

Table 10_e: Back-transformed mean catches and catch indices of pooled Horse flies in Umm Banein Locality using Nzi trap baited with fresh urine of equines.

Odour	Mean catch	Index	F-ratio
Donkey-Female	3.19	0.87	
Donkey-Male	3.30	0.91	
Horse-Female	3.66	1.00	
Horse-Male	3.76	1.03	0.069 ns
Control	3.65	1.00	1.969 ns

^{ns} ***P* > 0.05**

Table 10_f: Back-transformed mean catches and catch indices of pooled Horse flies in Umm Banein Locality using Nzi trap baited with fermented urine of equines.

Odour	Mean catch	Index	F-ratio
Donkey-Female	4.11	1.22	
Donkey-Male	3.14	0.93	
Horse-Female	3.91	1.16	
Horse-Male	2.51	0.74	0.506^{ns}
control	3.38	1.00	2.633^{ns}

^{ns} $P > 0.05$

Chapter Five

5. Discussion

Biting and non-biting blood-sucking flies associated with farm animals have high economic and public health importance because of their role as biological and mechanical vectors of diseases (Foil, 1989); the diseases agents include viruses (Rift Valley Fever), bacteria (hemorrhagic septicemia), Protozoa (Trypanosomoses). Furthermore attack of such flies disturb animals with following off condition and susceptibility to infection with microbial and parasitic diseases (Yagi 1968) impairment of grazing, feed conversion rate weight gain and production performance (Waage1979; Drummond *et al*., 1981). Comprehensive reports of horse flies gave description of their distribution; biology and ecology were published (Lewis, 1953; Yagi, 1968; Mohamed-Ahmed *et al*., 1997).

Sudanese nomadic has lead transhumant style of life due to the drought and high challenge of the biting flies. Domestic animals that have been kept under transhumant system of management represent over 80% of the Sudan livestock. These herds annually at the dry season, November-May, move to high land in the east or southward where pasture and water are plenty for grazing; where they might contact tsetse and consequently become infected with Animal African Trypanosomoses (AAT). By the advent of the rains in May the nomadic protect their animal from high challenge of horse flies (Diptera: Tabanidae) by migrating out (Thill, 1948) to low lands in the west and or northward for grazing.

The impact of the horseflies has prompted the present study to contribute to our knowledge of the species diversity, occurrence and responses of such flies to unbaite and baited traps in the area is well known as Fung region in order to develop a simple technology for sustainable control of the horse flies.

This will have vital obvious countrywide impact on the rural and pastoralist living standard. Hence transect entomological-surveys were conducted using unbaited Nzi, Biconical and Vavoua traps for biting flies prevalence during the different seasons using as possible the same trap sites. The traps were set 200 m apart to avoid intervention between treatments.

During the study era tabanid flies encountered comprise of *Atylotus agrestis, Tabanus taeniola*, and *T. sufis* roaming widely in the different habitats investigated. Whereas *T. par* and *T. sufis* were trapped in the *Acacia* woodland forest; *A. fuscipes, T. biguttatus, Philoliche magretti* and *Haematopota* species were caught in the relatively humid grazing raised ground. However, their distribution seems to have the same distribution reported previously (Lewis, 1953; Yagi, 1968; Abdel Razig and Yagi, 1975; Hall *et al*., 1984; Sawsan, 1997; Mohamed-Ahrned *et al*., 2007).

In the present work the Nzi trap was better one captured more and variety flies species including *Ph. magretti*; nevertheless the Biconical trap trapped more *T. biguttatus.* As far as to our knowledge this is the first ever record of trapping *Ph. magretti* and *T. biguttatus* with unbaited cloth-traps. Capture by a trap is the end point of a series of behavioral responses by the fly; including visual appearance and orientation (Vale, 1982) moreover it seems that the yield is accumulative results of using the right trap with the right person at the right time, place and site.

Tabanids are potential pests of man and domestic animals as vector of diseases or to cause annoyance (Foil 1989; Thomson et al 2000). Accurate data of the target tabanids seasonal abundance patterns allows identification of time when steps to minimize their impact are sensible. Attack on a vector based on a sound knowledge of its ecology (Jordan, 1974) has been argued to be the most promising approach for controlling. Hence in the present study the seasonal abundance pattern of the horse flies has been investigated using Nzi tap.

Prevailing species *A. agrestis*; together with *T. taeniola* were encountered with dissimilar densities right through the different seasons. The *A. fuscipes*, *T. biguttatus* and *Ph. magretti* were present during the rainy and cool-dry seasons while *T. sufis* was trapped in the cool and hot-dry seasons. *T. par* and *Haematopota* species were caught in the rainy and cool-dry season, respectively. The seasonal abundance patterns of different tabanids species have been investigated and described worldwide and in the Sudan (Miller, 1951; Pechuman *et al*., 1961; Hanec and Bracken, 1964; Yagi and Abdel Razig, 1972; Abdel Karirn, 1980; Hall *et al*., 1984; Ralley, 1986; Sawsan, 1997; Krernar, 2005; Mohamed-Ahmed *et al*., 2007; Faiza).

In the current work the majority of the horse flies are abundant during the rainy season (July-October); this finding is in similarity with the previous studies. The majority of the horse flies in most of the Sudan regions were found to be abundant during the rainy season which occurs from June to October (Yagi and Abdel Razig, 1972; Abdel Karirn, 1980; Hall *et al*., 1984; Sawsan, 1997).

In the present study the *A. agrestis* showed bimodal curve of flight; two peaks a smaller one signaling the start of the rain and a higher one at the end of the rainy season and the beginning of the cool-dry season (October- November). At the end of the rainy season and the beginning of the cool-dry season (October- November) *A. fuscipes, Tabanus taeniola, T. sufis, T. biguttatus, T. par, Ph. magretti* and *Haematopota* species showed one hump flight peak. However, two flight peaks for horse flies in Khartoum (Mohamed-Ahmed *et al*., 2007; Faiza,) were observed; a higher one occur at the end of the cool-dry and the beginning of the hot-dry season from March to April-May; and a smaller one at the end of the rainy and the beginning of cool-dry season from September to November.

The above observed variation in seasonal abundance might be attributed to the physiological characters which enable the individual to survive and adapt. The allocation and existence of an insect fly in a certain biotic is a result of reaction of genetic factors, controlling physiological and behavioral characters enable an individual to adapt, with the surrounding environmental elements comprised of abiotic (climate) and biotic (host, vegetation cover, diseases) factors (Mohammed, 2004).

Tabanids population occupies a wide band across the county (Lewis, 1952; Yagi and Abdel Razig, 1972; Abdel Karirn, 1980; Hall et al., 1984) this fact together with their reproductive behavior predicts occurrence of pronounced genetic variation among species. Hence the individuals' characters are much varying. Consequently their response against the surrounding limiting environmental factors in terms of susceptibility and resistance are varied. Consequently each species has specific ecological requirements and species which can withstand the limiting factors, are able to survive and present into various and wide ecological conditions. Nearly all females of tabanids species seek blood and dramatically differ in the level to which they are active throughout the day (Hollander and Wright, 1980; Ruth *et al*., 2002; Ruth *et al*., 2004; Gabriel *et al.,* 2008) which is usually related to simultaneous changes in environmental conditions including saturation deficit, temperature, light intensity and wind speed (Mc Elligott and Galloway, 1991; Mohamed-Ahmed *et al*., 2007).

The significant importance imposes tabanids control yet strategies for tabanids control are limited. Many control procedures have been evaluated in attempts to reduce horse fly population attacking livestock, but few have given a satisfactory reduction of populations. Residual insecticides on animals (Bay *et al*.,1976: Harris and Oehler, 1976: Presley and Wright, 1986) and insecticide spraying directed into the wooded edges of a recreational area have given short-term reduction (Hansens, 1981) and provided only unpredictable to poor control of horse flies (Howell *et al.*, 1949) moreover is expensive, calls for detailed monitoring of deleterious effects on the environment. Sticky traps did not adequately protect cattle from these pests (Wilson, 1968).

Control by modification of environment via destroying breeding sites is outmoded, unacceptable, and expensive and at the end efficacy is not assured. Hence ultimate success of control depends on selecting appropriate techniques for the target pest species (Foil and Hogsette, 1994). Method for controlling the impact of tabanids must be linked the life cycle and host dependence. In this context, control by using baits such cloth-traps is perceived as the most appropriate approach (Green, 1994); but there is often convergence of trap shape and colour.

Efforts to develop a simple trap, non-technical, economical with minimal bias in efficiency, specific and mimic an attractive host have continued to date. Cost effective design and multipurpose trap Nzi (Mihok, 2002), for use in community-based control and population monitoring has been constructed.

In the present work with the purpose of realize the best trap for the local horse fly population, the Nzi, baited-Nzi, modified-Nzi, Blue-biconical, Turquoise-biconical, and Vavoua traps were investigated. The efficiency of each trap was estimated and compared with others to select the most effective for sampling and the most cost-effective for control purposes.

The Nzi trap was designed for equitable efficiency for tsetse, stable flies and Tabanids. It has been tested extensively elsewhere in Ontario, Canada with exploratory work at other locations in North America (Mihok *et al.*,) but few studies have been conducted in the Sudan. Experiments were therefore initiated to investigate the suitability of the trap.

The performance of Nzi, Blue-biconucal traps, Turquoise-biconical, and Vavoua was determined using the appropriate Latin squire design. Regardless of type of vegetation the Nzi trap caught significant (P<0.001) more horse flies than the biconical traps or the uncomplicated and inexpensive Vavoua trap. The Biconical trap and its modification were as efficient as each other and the Blue-Biconical trap trapped significantly more flies than the Vavoua trap. Unfortunately, the obtained result demonstrates clearly that the simpler Vavoua trap is significantly ($p < 0.002$) not as efficient as the Nzi and the more complex Biconical trap. These results confirmed the confidence that the Nzi trap was significantly more effective against the species of the horse flies than the other traps Mihok, (2002).

Similarly studies carried out by Mohamed-Ahrned *et al.*, (2007) indicated that Nzi trap was the best trap for monitoring and control of horse flies in Sudan compared with canopy, NGU2b and biconical traps, because it caught various species in different climates, high numbers of flies entering trap, more economic than other conventional tabanids traps and the Nzi trap is easy to make. It typically catches more biting flies than other traps, which are often optimal for just a few groups. Except for large interception traps such as the Malaise, good trap performance for all species is difficult to achieve (Gibson and Torr, 1999). Since the obtained results have revealed that the original Nzi trap is effective against the horse flies, easy to erect and transport its use for controlling tabanids especially in remote locations is highly recommended.

The discoveries of natural and synthetic odours coupled with improvements in trap design have greatly increased the effectiveness of traps for survey and offer the possibility of controlling tabanid flies using odour-baited traps (Foil and Hogsette, 1994).

In the present study the colour of the vertical wings shelf, the horizontal or the three panels were changed into black colour to improve the efficiency of the orignal Nzi trap. The three modifications of the Nzi trap caught 2.6, 2.4 and 1.5 times more pull flies than the orginal Nzi trap, yet they were statistically insignificantly ($p > 0.5$) better than the original Nzi trap. The modifications affected trap efficiency which differ between tabanid species. Various earlier works with more or less alike consequences that depend on modifications of visual appearance of traps for improvement of traps catches (Roberts, 1972; Phelps and Holloway, 1992) have been described.

Synthetic attractants in traps are universally (Foil and Hribar 1995) used to attract hematophagous *Diptera*. Studies of attractants assist to recognize the host finding process and may be valuable tools in monitoring and controlling biting flies (Nilssen 1998; Mohamed-Ahmed and Mihok, 1999).

Efficacy of tabanid traps is mainly increased by adding chemicals that mimic natural host odors (Hall and Wall 2004). Some of the synthetic attractants significantly increased the catch of tabanids in Africa (Foil and Hribar, 1995; Gibson and Torr, 1999). Furthermore some natural attractants such as the aged urine of a number of domestic and wild bovids contain some phenolic compounds significantly attracted most species of tabanids (Mihok *et al*., 1996; Krčmar *et al*., 2006). So far little is known about the presence of key attractants in the aged urine moreover it is still not clear if urine from other mammals is useful for collecting tabanids. Therefore, this study considers the effects of fresh and aged cattle, camel, equines, sheep and goats urine on catching tabanids in eastern region of the Sudan.

In the present study generally fresh as well as ageing urine of small ruminant depressed the yield of tabanids yet did not significantly affect the Nzi trap catches, while fresh and ageing urine of large ruminant as well as from equines enhanced the trap catch but no significant differences were seen this might be due to the significant interaction between days. Also the bulk of tabanids were collected in Nzi traps baited with fresh or aged cow or horse-female urine. These findings are in agreement with Okech and Hassanali (1990) ones elucidated that fresh urine is not attractive for tabanids. Results with aged cow, horse and sheep urine were very similar and not significant for

Haematopota pluvialis and *Tabanus sudeticus* (Krčmar *et al*., 2006). However, the catches of some *Glossinidae* species, such as *Glossina austeni*, with traps baited by urine did not increase significantly (Vreysen *et al*., 2000).

On the other hand, the positive response of some *Glossinidae* species towards urine was observed (Brightwell and Dransfield 1997). Likewise, when dispensed at the known natural doses of ox odour, a synthetic attractants were about half as effective as natural ox odor in the collection of *Glossinidae* species (Hargrove *et al*., 1995). Madubunyi *et al*., (1996) found that aged cow urine significantly increased the catch of some species of tabanids. Bacteria convert trace chemicals in the urine to phenolic compounds that attract some species of tsetse, as well as most tabanids. Krčmar *et al*., (2005) showed that aged horse urine baited traps collected significantly more females of *Tabanus sudeticus* than did traps baited with synthetic attractants.

Although numerous studies have demonstrated that aged cow or horse urine baited traps appeared to be the best collection methods for tabanids (Okech and Hassanali, 1990; Krčmar *et al*., 2006). Yet the present results suggest that fresh as well as aged urine of tested animal species did not influence significantly the catches of tabanids in baited Nzi trap. The present studies were carried out in small man-made habitat comprised of fodder plots, irrigation canals, few animals and shade trees that is expected to support a limited tabanids population of 325; *A. agrestis* (80.31%), *T. sufis* (15.69%) and *T. taeniola* (4.13%).

Thus practicing daily trapping may lead to catching-out of flies consequently adversely influence the number of flies attracted to the tested odour-bait although these odour are potent attractant for the same species of flies in a similar setting in an extensive habitat. Such habitat limitation must be considered when screening olfactory attractants for tabanids. Aged urine of domestic animals in traps could result in the reduction of tabanids. Hence further studies are needed to assess the attractiveness of domestic-urine for tabanids flies, yield composition, the way in which they respond, and how such odour enhance the efficiency of traps.

Conclusion

- Nine species of tabanids belonging to four genera: *Tabanus taeniola, T. gratus, T. sufis, T. par, T. biguttatus*, *Atylotus agrestis, A. fuscipes, Philoliche magretti* and *Haematopota* species were identified in the present work.

- This is the first ever record of trapping *Ph. magretti* and *T. biguttatus* with a cloth-trap, hence it seems that the catch is a results of using the right trap with the right person at the right time, place and site.

- The majority of the horse flies are abundant during the rainy season showed bimodal curve of flight; a smaller peak signaling the start of the rain and a higher one at the end of the rainy season and the beginning of the cool-dry season.

- Nzi trap is an efficient tool for sampling tabanids and caught significantly more flies than the Biconical and Vavoua traps.

- The modified Nzi traps caught more tabanids, yet they were not significantly better than the original Nzi trap.

- Generally fresh as well as aged urine of domestic animals tested did not influence significantly the Nzi trap catches. Since they are known potent attractant hence further they needed to be assessed in a similar setting in an extensive habitat.

Recommendations

1- The tabanids movement and survival should be studied by applying the gene-follow technique.
2- Different natural and synthetic odours need to be studied to improve the reaps
3- The extension should contribute towards raising the community awareness to the benefit from the use of environment-friendly insect control bait techniques.

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Appendix

The Nzi tarp (Mihok (2002)

Small ruminates………fresh urine

Total Tabanids

	day 1	day 2	day 3	day 4	day 5	total
side 1	a1.342	c1.079	d1.146	e1.041	b.301	4.909
side 2	c1.113	d1.176	e.903	b1.000	a1.000	5.192
side 3	d1.505	e1.204	b1.176	a1.113	c1.000	5.998
side 4	e.845	b.602	a.301	c.301	d.301	2.35
side 5	b1.414	a1.079	c1.612	d1.653	e1.431	7.189
						25.638
side 6	b.301	e.477	c.301	d.778	a .301	2.158
side7	a.477	b.602	e 000	c.301	d,301	1.681
side 8	d.602	a.477	b.602	e.698	c.301	2.68
side 9	c.301	d.602	a.778	b 000	e.301	1.982
side 10	e.698	c.301	d.477	a 000	b 000	1.476
						9.977
Total	**8.598**	**7.599**	**7.296**	**6.885**	**5.237**	**35.615**
	A	**B**	**C**	**D**	**E**	
	6.868	**5.998**	**6.61**	**8.54**	**7.598**	

ANOVA

Source of variation	df	SS	MS	F- ratio	Probability
Replicate	01	4.905			
Site within Replicate	08	2.727	0.341		
Treatment	04	0.383	0.096		
Day	04	0.604	0.151	2.043^{ns}	P>0.05
Residual	32	1.489	0.047	3.213^{*}	
Total	**49**				

Index

Treatment type	Mean (x)	Trans mean G	Index

A	0.6868	3.86	0.81
B	0.5998	2.98	0.63
C	0.6610	3.58	0.75
D	0.8541	6.15	1.29
E	0.7598	4.75	1.00

Ranking

B: 0.5998

C: 0.6610 SSR= 0.2801 P>0.05

A: 0.6868 AD= 0.2543^{ns}

E: 0.7598

D: 0.8541

Since the actual difference (AD) is less than the calculated short significant range (SSR), thus the highest (D) and lowest (C) means are not significantly different