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Deltamethrin 10%-Impregnated Screens Pitched in a Tsetse Endemic Area in the Sudano-Sahelian Region of Cameroon Reduce Tsetse Fly Density and Trypanosomosis Incidence

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Abstract

A field trial was conducted in order to evaluate the efficacy of Deltamethrin-impregnated screens in a tsetse endemic zone in Cameroon over a period of 26 months (September 2011 to October 2013). Tsetse barriers consisted of Deltamethrin-treated odor-baited targets (n = 376), deployed on Bini pasture. Similarly, biconical traps were also installed (100 - 200 m apart in each site) for 48 h during sampling (the beginning and the end of the dry and the rainy seasons), and screen density was 1 screen per 100 m^2. Parasitological and hematological analyses were carried out using standard protocols, namely, the Buffy Coat Examination (BCE) and hematocrit evaluation. Trypanosomes identified included: *Trypanosoma congolense*, *T. vivax*, and *T. brucei brucei*. Overall fly catch was 1491 flies (*Glossina m. submorsitans* and *G. tachinoides*). The overall mean apparent density of flies before deployment of traps was 28.9 flies/trap/day (F/T/D)±12.48 SD, which was significantly higher ($P > 0.05$) than the density post screen installation of 18.4 F/T/D ± 5.67SD. BCE positive samples, and PCV did not show a statistically significant difference ($P > 0.05$) with season. Disease incidence was not significantly different ($P > 0.05$) before or after the deployment of screens. Body weight was significantly different ($P < 0.05$), while BCT and PCV were not significantly different ($P > 0.05$) pre or post-intervention with screens. Body weight was significantly different ($P < 0.05$) between seasons, while BCT and PCV were not ($P > 0.05$). In conclusion, screens readily cleared tsetse infestation and reduced trypanosomosis incidence, as well as improved host health and reduced related risk factors in the area.

Keywords: Deltamethrin-impregnated screens, cattle, tsetse control, trypanosomosis, Cameroon

Introduction

Animal trypanosomosis is prevalent where tsetse fly (genus: *Glossina*) and other haematophagous flies occurs. However, the general consensus is that trypanosome species causing the disease in cattle (*T. vivax, Trypanosoma congolense*, and *T. brucei brucei*) are tsetse borne. This important phrase is supported by the finding of the Scottish missionary and explorer David Livingstone (1813 - 1875) who first suggested that nagana (cattle trypanosomosis) is caused by the bites of tsetse flies. A report has already been made on the unimportance of other biting flies apart from tsetse flies in the epizootiology of this disease in Adamaoua [1]. The most compelling evidence for this is that when tsetse flies were eliminated from large areas of Zimbabwe, Botswana, and South Africa, trypanosomosis ceased, even though potential mechanical vectors such as stable flies and horse flies were still abundant and might be subsequent factors for re-emergence of the disease in such zones.

Bovine trypanosomosis is a serious constraint to agricultural production in extensive areas of the tsetse-infested Guinean savanna areas and Soudano-sahelian region in Cameroon [1-3]. Although livestock trypanosomosis is a well-known constraint to livestock production in Cameroon, little attention has been paid to the trypanosomosis situation in the Soudano-Sahelian region. Overgrazed pastures, increasing population, and the need for animal protein in the Adamaoua region have forced cattle owners to establish themselves in the Mayo Rey, which is one of the most vast divisions in Cameroon, with a land mass of about 36.524 km². Before the year 2009, herders of the Adamaoua plateau conducted transhumance only to the Mayo Rey, so that their animals can graze on corn and millet. The ability of cattle to browse over trees to consume leaves in this area enables them to seek for extra nourishment during the dry season.

The herds of cattle that arrived in this area in 2009 generated low income, with great losses. According to the perception of cattle owners, many clinical cases were due to trypanosomosis. Overpopulation in this area is induced by farmers escaping from ethnic conflicts in the Central African Republic, and also by those escaping from the Nigerian Islamic group Boko Haram. Nevertheless, livestock is the backbone of the rural economy of this region, because approximately one third of the Cameroonian cattle and small ruminant population is found here. Trypanocides might be an effective control method in all circumstances where a drug does not impair animal health [4]. Treatment is mostly carried out by livestock owners themselves, without any supervision by veterinary personnel. Moreover, most of the products are purchased from illegal veterinary shops, and are cheap but fake. It is rather unfortunate that farmers themselves abuse the usage of such fake drugs (by either under–dosing or overdosing), leading to the development of drug resistance [5,6]. Insecticide-treated cattle could also serve as an important control method [7]. However, the disadvantage of this method is that, although treated cattle are required to sojourn near tsetse habitats in order to kill a large number of flies, the treatment does not protect the cattle against trypanosome transmission [8]. The upshot is that reliance on a few insecticide-treated cattle alone is unlikely to be satisfactory [8]. The extensive clearing of vegetation for crops in an area makes it unsuitable for permanent occupation by a self-sustaining population of tsetse. The aim must be to prevent occasional or seasonal invasions from adjacent wilderness. This requires an invasion barrier at the cattle/tsetse interface.

The use of targets as a tsetse fly control tool is estimated to cost between 220 - 290 US$ in flat terrain, which is relatively cheap as compared to other traditional control measures [9]. Hence, odor-baited targets are probably suitable tsetse control techniques. An overall 94.9 % fly reduction using targets has been achieved in Ethiopia, as reported by Bekele *et al*. [10]. However, insecticide-treated screens (targets) and traps have similarly been used with varying success in different parts of Africa, as reported by the following authors- Muhanguzi *et al*. [11] in Uganda; Courtin *et al*. [12] in Guinea; Lindh *et al*. [13] in Kenya; Girmay *et al*. [14] in Ethiopia; Rayaisse *et al*. [15], and Ayano *et al*. [16]. The purpose of this study was to provide ample information in order to model the control process quantitatively, and to investigate the effectiveness of an area-wide barrier of insecticide-treated targets in the Soudano-sahelian regional context of Cameroon, being subject to tsetse fly re-invasion from neighboring south of Chad.

Materials and methods

Study area

The river Bini, from which the name of the study area (Bini) originates, has its source in Ngaoundere, and flows along the Mayo Rey division (Northern savanna) right up to the river Logone in Chad (**Figure 1**). The study zone (Bini) covers an area of approximately 100 km^2 along the river side. High plateau, hills, and valleys characterize this area. The climate is divided into 2 main seasons: a rainy season from May to September, and a dry season from October to April. The Savanna-type vegetation consists of African peach, Karité, and *Annona senegalensis* in abundance. About 95 % of the population lives in rural areas and practices subsistence farming and rainy season cropping, together with extensive grazing of livestock. The Northern savannah which harbors this study area has the following land use pattern: 31 % cultivated, 0.6 % pasture, 2.6 % gallery forests and bush, 40.3 % savannah, 2.6 % wetland, and 23 % classified as utilizable land [17]. This area of the North region is tsetse infested. The Bini pasture area was chosen for this study because it is an infested area, where several cases of animal trypanosomosis have been observed.

Protected parks (such as Benoue National Park, Bouba Njida National Park, and other private game reserve areas) are found sideways of the river Bini in Mayo Rey and harbor wild animals such as giraffes, hyenas, lions, monkeys, and bush pigs. Chemotherapy, screens impregnated with Deltamethrin, the spraying of herds, local bush fires (used as anti-fly), and insecticide pour-on formulations are trypanosomosis control methods used in this area. Veterinary supervision is inadequate because of the large land mass and insufficient number of veterinarian helping hands. This situation has led to the inappropriate usage of standard drugs and drugs of substandard quality from neighboring countries such as Chad, Nigeria, and the Central African Republic.

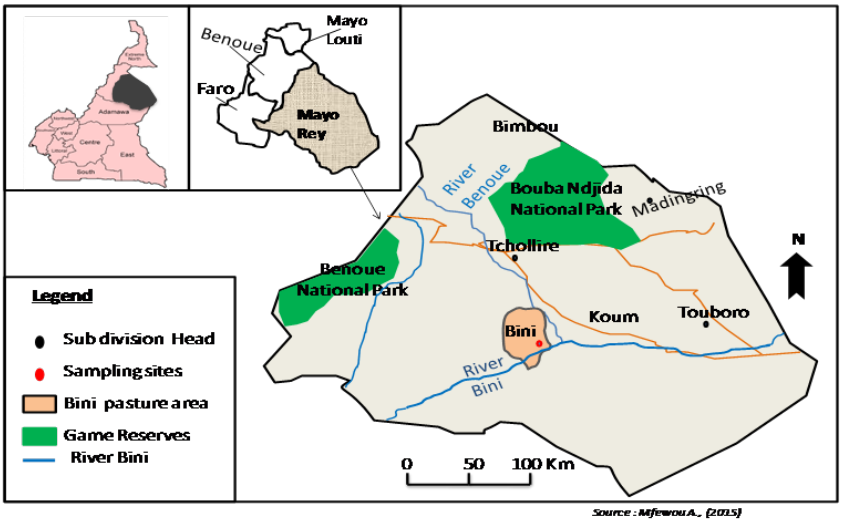

Figure 1 Map of study area Mayo Rey.

Sample selection

The study was conducted from November 2011 to October 2013. This study covered 13 sites: Mayo Kombo, Mayo Yoko, Mayo Mbao Daouda, Laide Ngawa, Mayo Ouro Dara, Mayo Bini, Bangalan, Saltel, Walouwol Bini, Laigua Bali, Mayo Make, Mayo Riz, and Mayo Doubbi, falling within the geographical limits of 7°, 36,303' N - 14°, 26,396' E and 7°, 53, 435' N - 14°, 37,809' E (**Figure 2**). Cattle in this region consist of indigenous zebus (Gudali and Mbororo-Fulani). Fourteen of 70 local cattle herds of animals were selected following group meetings arranged with herdsmen and livestock owners from the various sites. Participants in those meetings provided details on the number and composition of their stock holdings. Herdsmen indicated homestead positions, grazing areas, and drinking points. During each sampling, a total of 140 animals (10 animals/herd) were randomly selected from the available herds.

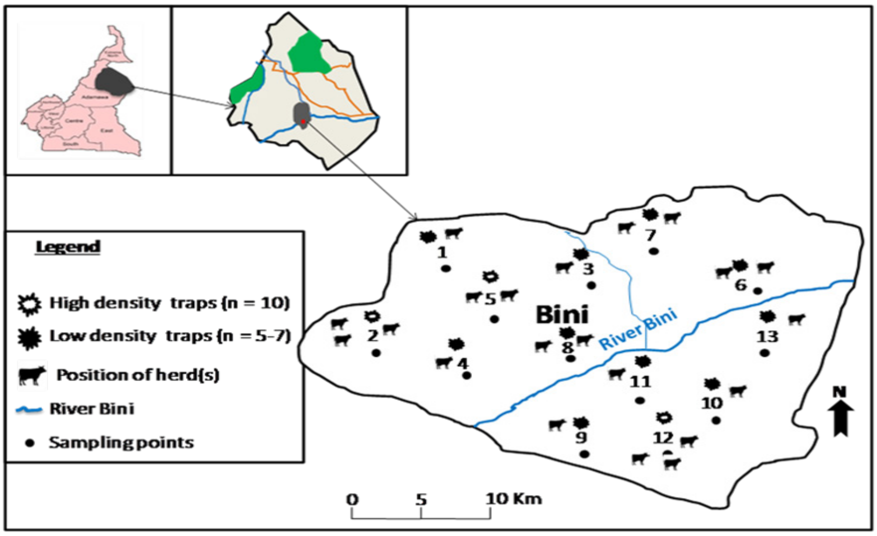

Figure 2 Map of study site (Bini) showing position of herds and trap densities at various sampling sites.

Parasitological diagnosis

Annually, at the beginning and end of both seasons (dry and rainy), 140 animals were sampled. The parasitological diagnostic tests used were those described by Paris *et al.* [18]. Briefly, blood was collected from an ear vein into heparinized tubes. Part of this was used to make thick and thin blood smears and the remainder introduced into microhaematocrit capillary tubes. The capillary tubes were sealed with "cristoseal" (Hawksley) and centrifuged for 5 min at 9000 g. After centrifugation, the packed cell volume (PCV) was determined. Animals with PCV ≤ 25 % were considered anaemic. Buffy coat region content of the micro-hematocrit tube was extruded onto a microscope slide and examined under phase contrast microscope with ×40 objective lens for the presence of motile trypanosomes. The thick and thin blood smears were stained with Giemsa and examined under a light microscope using a ×100 oil immersion objective lens in order to ease identification through distinct morphological characteristics. Weight of cattle was estimated using a veterinary tape for measuring weight of cattle and pigs [3].

Entomological sampling

Sampling started at the beginning of the dry season (November 2011) in 13 sites. The population of biting flies was monitored using 5 to 10 biconical traps [19] baited with cow urine and acetone [20]. Traps were deployed at positions of about 100 - 200 m apart at each site (**Figure 2**). The site covered various vegetation types of pasture, relevant for tsetse sampling, along the banks of the river Bini. The coordinates of each trap position was recorded using a portable global positioning system (GPS) device (GPS eTrex®; Garmin (Europe) Ltd, Southampton, U.K.). Trapping sites corresponded to those areas visited by livestock for drinking. Individuals in this community were sensitized on the various trap-types, uses, and exposition periods of this trap. This was to ensure that our efforts were supported by this community, so as to achieve efficient goals in an area, like the Bini pasture area of Mayo Rey, which was new to such an intervention.

Pre-target installation and monitoring activities

Tsetse survey and incidence monitoring (pre-intervention) took place from the beginning of the dry season (November 2011) to the end of the rainy season (October 2012) in 13 sites. A number of tsetse traps (n = 5 to-10) were pitched along the river Bini per site according to the number of herds in the vicinity. Tsetse flies were collected from each trap twice a day for a period of 48 h and sorted according to species, habitat, morphology [21,22], and sex [23]. Random-sampling of 10 animals in 14 herds (n = 70) was made for parasitaemia and haematocrit analysis using standard protocols.

Post-target monitoring phase

A total number of 376 Deltamethrin-impregnated screens (**Figure 3**) were deployed in 13 sites on the pasture of Bini, from November 2012 (the start of the dry season) to October 2013 (the end of the rainy season) (**Figure 4**). The coordinates of each screen position were recorded. They were impregnated 2 times per month during the rainy season, and once per month during the dry season, with Deltamethrin 10 % until the end of the experiment. One screen was pitched in between the 100 m-biconical trap transect, resulting in a screen density of 1 screen per 100 m^2, to cover the screen sample area. Installation of tsetse traps ahead of coated screens took place during this period, in order to assess the vector apparent density post-target deployment. Random sampling of 10 animals in 14 herds (n = 70) was again carried out in order to assess the level of parasitemia and hematocrit changes post-target implantation.

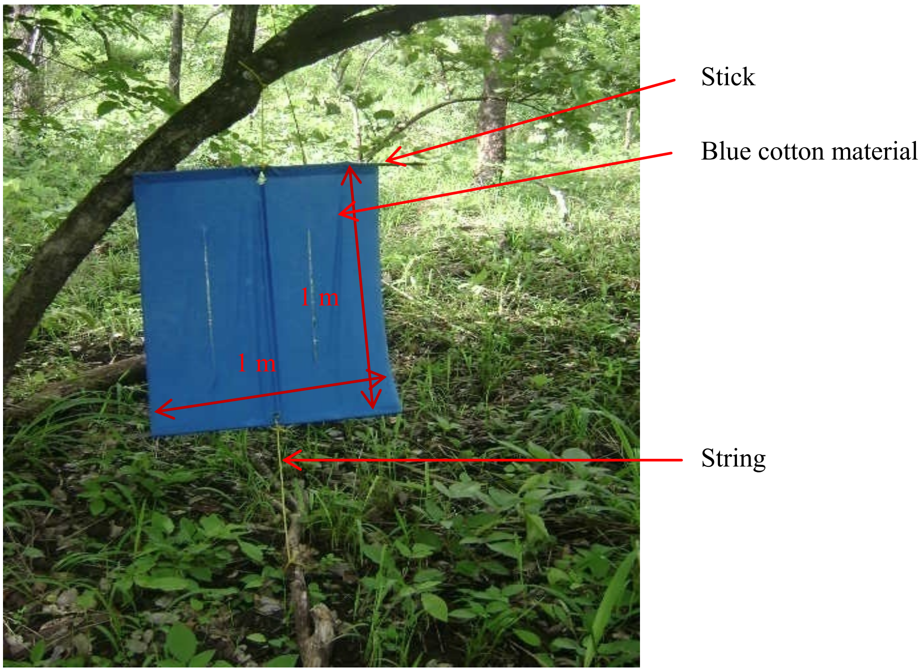

Figure 3 Deltamethrin-impregnated screen.

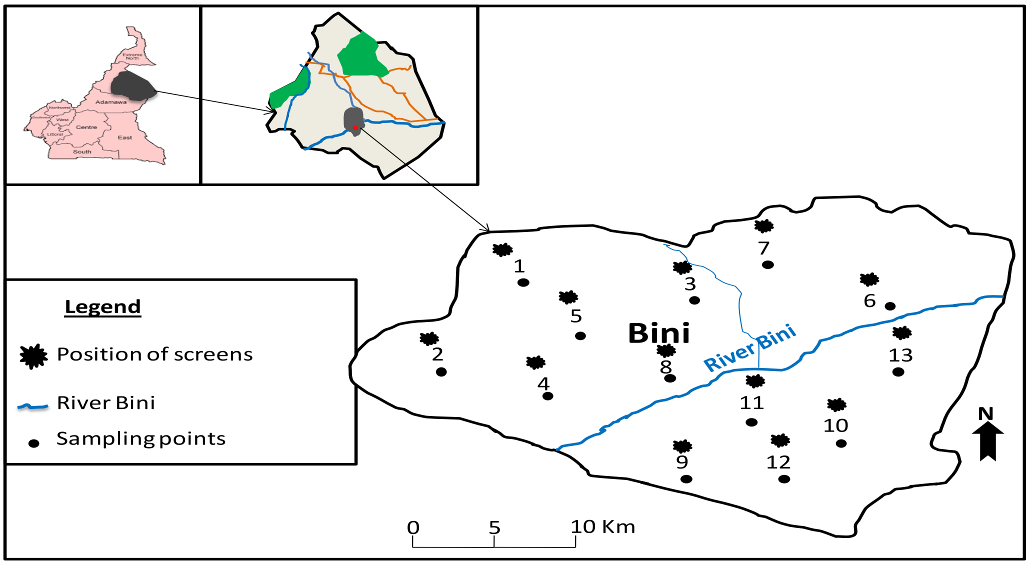

Figure 4 Map of Bini showing the position of screens at various sampling sites.

Data analysis

The abundance of *Glossina* spp. caught was evaluated by the mean trap apparent density (TAD). This was calculated using the following formula, as used by Zinga Koumba *et al*. [24];

$$\text{TAD} = \frac{\text{NFC}}{\text{NTs} \times \text{TDs}} \tag{1}$$

where,
NFC = Number of flies captured
NTs = Number of traps
TDs = Number of trapping days

Reduction in both fly number and trypanosomosis incidence cases was realised using the following formula, already used by Acapovi-Yao *et al*. [25];

$$\text{Reduction rate} = \frac{\text{ADTi}-\text{ADTf}}{\text{ADTi}} \times 100 \tag{2}$$

where ADT_i is the initial apparent density of flies, the same for incidence before the deployment of a control tool (screens), and ADT_f is the final apparent density or incidence following the deployment of screens.

Statistical analyses

SPSS version 17.0 was the statistical software used to carry out the analysis. Parameters such as buffy coat (BCT), PCV, and weight were compared before and after the deployment of screens using the student t-test. The same parameters were compared according to the season. Apparent fly density before and after the deployment of screens was also compared using the student t-test. Duncan's test was used to compare apparent density of flies by sex according to the period of trapping, and represented graphically. This same test was also used to compare the mean BCT and PCV according to breeds, and was also represented graphically. The significance level for all tests was stated at $P < 0.05$.

Results

Cattle health and related risk factors before and after the implantation of screens

Trypanosomes identified in the blood of cattle during the field trial consisted of, *T. congolense*, *T. vivax*, and *T. brucei brucei*. Indicators of cattle trypanosomosis are known to consist of state of weight, PCV, and BCT. To begin with, the mean weight of cattle before the implantation of traps was low (299.8±39.75 SD) as compared to high (331.32±45.02 SD) weight after intervention with Deltamethrin-impregnated screens. The mean PCV before the deployment of Deltamethrin-coated screens (30.40±1.92 SD) was slightly lower than after the deployment (32.76±3.89 SD), and this reduction was not significantly different ($P > 0.05$). Based on the number of positive cases in the buffy coat test (BCT), in the population of cattle at risk, the mean positive BCT before the installation of screens was (0.53), which was higher than the value (0.4762) after their installation; however, this difference was not significantly different ($P > 0.05$) from the value obtained from Deltamethrin-coated screen application code (**Table 1**). It was observed that only weight showed a statistical significant difference ($P < 0.05$) according to season (**Table 2**). The other parameters, such as BCT and PCV, did not differ significantly ($P < 0.05$) with season (**Table 2**).

Fly apparent density before and after the deployment of screens

A total of 1491 Tsetse flies were captured, consisting of *G. morsitans submorsitans* and *G. tachinoides* of either sex. The species living on the savanna (*G. morsitans submorsitans*) constituted a greater part of the captured flies than the riverine species (*G. tachinoides*). More females of both species were captured than males. The apparent density of flies captured before the deployment of screens (28.92±12.48 SD) was significantly higher than the density after screen deployment (18.40±5.67 SD) with a significant difference ($P < 0.05$). A fly density reduction of 43.17 % was thus recorded after screens were used (**Table 3**). Generally, *G. morsitans* capture-density before and after the installation of screens showed a statistically significant difference ($P < 0.05$), but, when their densities before and after the deployment were compared, *G. tachinoides* did not ($P > 0.05$). Male and female *G. tachinoides* and female *G. morsitans* apparent densities were significantly different ($P < 0.05$) before and after the deployment of Deltamethrin-impregnated screens (**Table 3**). *G. morsitans* males did not show a significant density difference ($P > 0.05$) before or after the installation of this target (**Table 3**).

Trypanosome incidence trend with season of deployment of screen

It was observed that, in the absence of targets (Deltamethrin-impregnated screens) in the sampled sites, the incidence of trypanosomosis increased at the beginning of the rainy season, and attained peak values at the end of rainy season, but declined steadily through the early dry season when the lowest cases were observed and, finally, at the end of the dry season of 2011, before the installation of screens. After the deployment of screens at the beginning of the dry season of 2012, the incidence of cases dropped through the beginning of the dry season of 2012 (20 %) to the lowest incidence values at the beginning of the rainy season of 2013 (12.14 %). A prevalence increase commenced at the end of the rainy season of 2013 (12.87 %), post-target deployment period. Generally, in the absence of screens, incidence was on average 26.25 %, which was higher than the 14.645 % obtained in the presence of screens (**Figure 5**); this gave a screen incidence reduction of 55.79 %.

Table 1 Effect of screen deployment on cattle weight, PCV, and BCT.

Parameter	Application code	N	Mean±SD	P < 0.05
Weight	Before	420	299.8571 ± 39.7543	
	After	280	331.3214 ± 45.02532	0.000
PCV	Before	420	30.4000 ± 1.92261	
	After	280	32.7607 ± 3.89604	0.377
BCT	Before	420	0.5321	
	After	280	0.4762	0.332

Legend: SD = standard deviation, P < 0.05 = level of significance.

Table 2 Effect of season on cattle weight, PCV, and BCT.

Parameter	Season	N	Mean±SD	P < 0.05
Weight	Dry	280	299.8929 ± 40.48526	
	Rainy	280	331.8571 ± 43.23124	0.001
PCV	Dry	280	30.4571 ± 1.97247	
	Rainy	280	30.6321 ± 2.65664	0.377
BCT	Dry	280	0.4857	
	Rainy	280	0.5714	0.332

Table 3 Fly density before and after the deployment of screens, based on species and sex.

Flies captured	Deployment code	Mean F/T/D	P < 0.05
Flies trapped	Before	28.9231	
	After	18.4038	0.000
G. morsitans	Before	10.2692	
	After	1.7404	0.000
G. tachinoides	Before	1.0269	
	After	0.9635	0.434
G.morsitans male	Before	0.6788	
	After	0.6213	0.335
G. morsitans female	Before	1.0615	
	After	0.3212	0.000
G. tachinoides male	Before	0.6481	
	After	0.3788	0.000
G. tachinoides female	Before	0.6481	
	After	0.1885	0.000

Hematological and parasitological relationships according to breed code

Trypanosomosis prevalence values were observed to be different over various breeds, such as Gudali, White Fulani, and Red Fulani. White and Red Fulani did not show a significant difference ($P > 0.05$) according to their mean BCT values. However, there was a statistically significant difference ($P < 0.05$) when their mean positive BCT was compared to that of Gudali. Gudali recorded the lowest prevalence values as compared to Red Fulani, with the highest positive buffy coat cases (**Figure 6**).

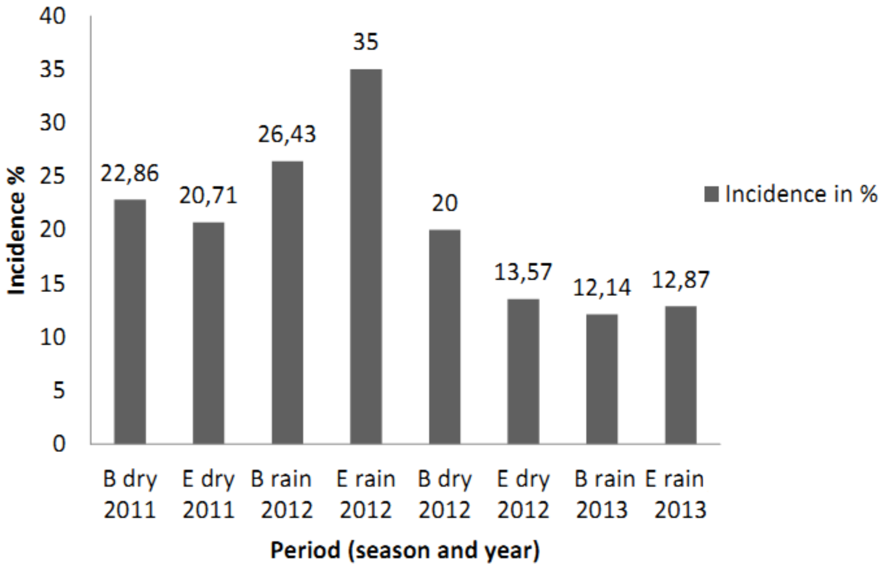

Figure 5 Trend of incidence trypanosomiasis with period of deployment of insecticide-impregnated screens.
B = beginning of season and E = end of season

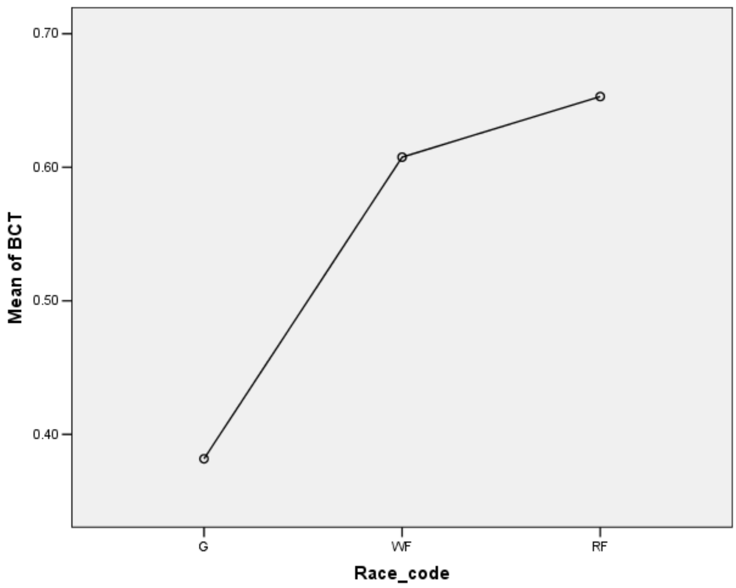

Figure 6 Duncan[a,b] represented graphically: Relationship between BCT and breed code.
G = Gudali; WF = White Fulani; RF = Red Fulani

Based on the relation of mean PCV with breeds, Gudali recorded the highest mean PCV (> 31.6 %) as compared to the White Fulani (> 31.0 %) and Red Fulani PCV (> 25 %), but values were not significantly different (P > 0.05), and White Fulani and Red Fulani did not show any statistical significant difference (P > 0.05). Gudali recorded a significant difference (P > 0.05) in mean PCV as compared to the rest of the breeds (**Figure 7**). It is important to note that, using the anemic cut-off value of 25 %, there were no anemic cases recorded, since the lowest PCV (> 25 %) value was recorded with red Fulani.

There was no significant difference (P > 0.05) in mean *G. morsitans* male catch at the end of the dry season of 2011, the end of the rainy season of 2012, or the end of the rainy season of 2013. But these densities were significantly different (P < 0.05) from those obtained at the beginning of the rainy season of 2013, and also significantly different (P < 0.05) from those obtained during the beginning of the rainy season of 2012 and from the beginning of the dry season 2011, of which these 2 did not differ statistically (P > 0.05) (**Figure 8**). Based on the mean *G. morsitans* female catch dynamics with season, there was no significant difference (P > 0.05) during the following periods: the beginning of the rainy season of 2013 and the end of the rainy season of 2013. There was a significant difference (P < 0.05) in the density of female *G. morsitans* throughout the other trial periods (**Figure 9**). Based on male *G. tachinoides*, there was no significant difference (P > 0.05) in their catch during the following periods: the beginning of the dry season of 2011, the end of the dry season of 2011, and the beginning of the rainy season of 2013, but there was a significant difference (P < 0.05) in the sex of this species with respect to other trapping periods (**Figure 10**). Also, there was no significant difference (P > 0.05) in the density of female *G. tachinoides* during the following trapping seasons: the beginning of the rainy season of 2013 and the end of the rainy season of 2013. A marked significant difference (P < 0.05) was observed during the other trapping periods (**Figure 11**).

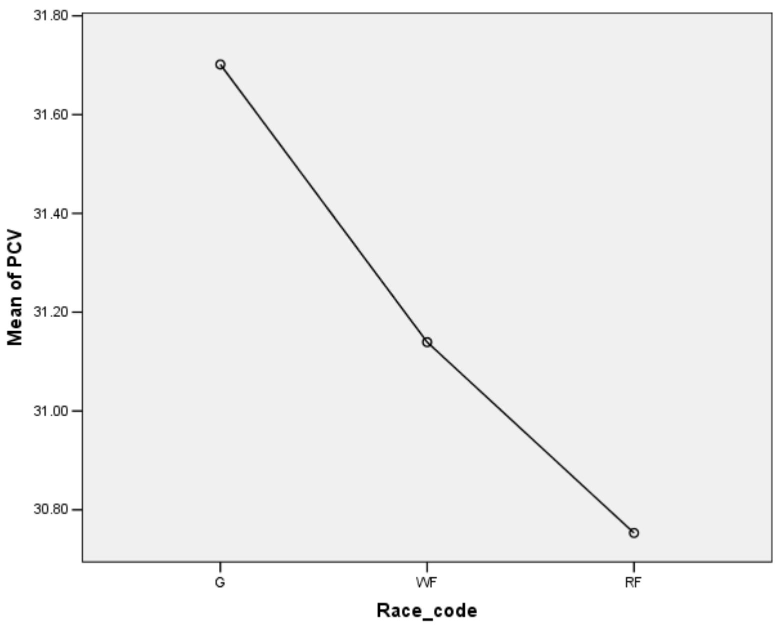

Figure 7 Relationship between mean PCV according to breed code.
G = Gudali; WF = White Fulani; RF = Red Fulani

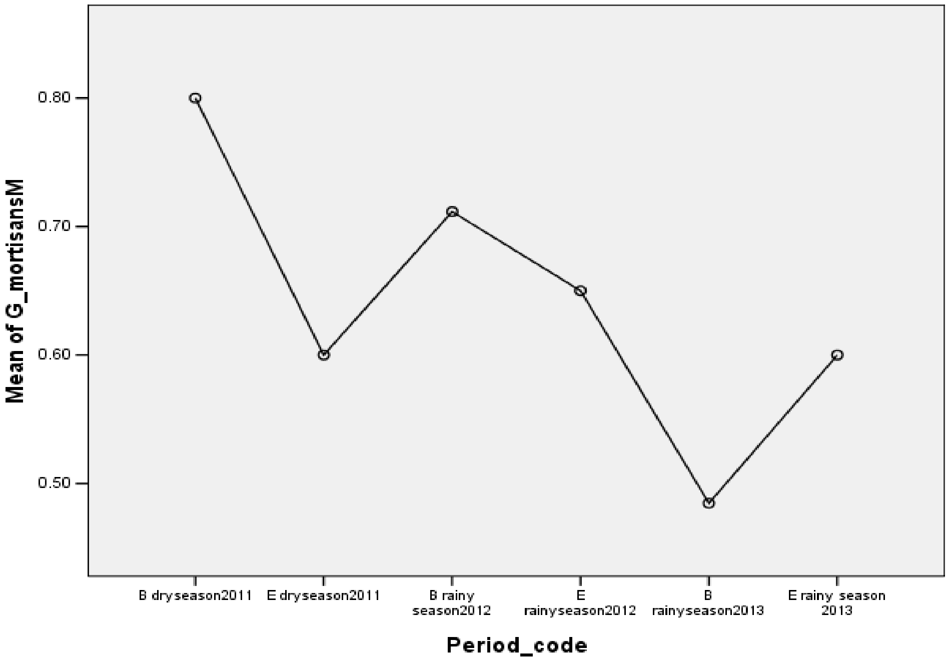

Figure 8 Density of *G. morsitans* males, according to season and screen deployment.

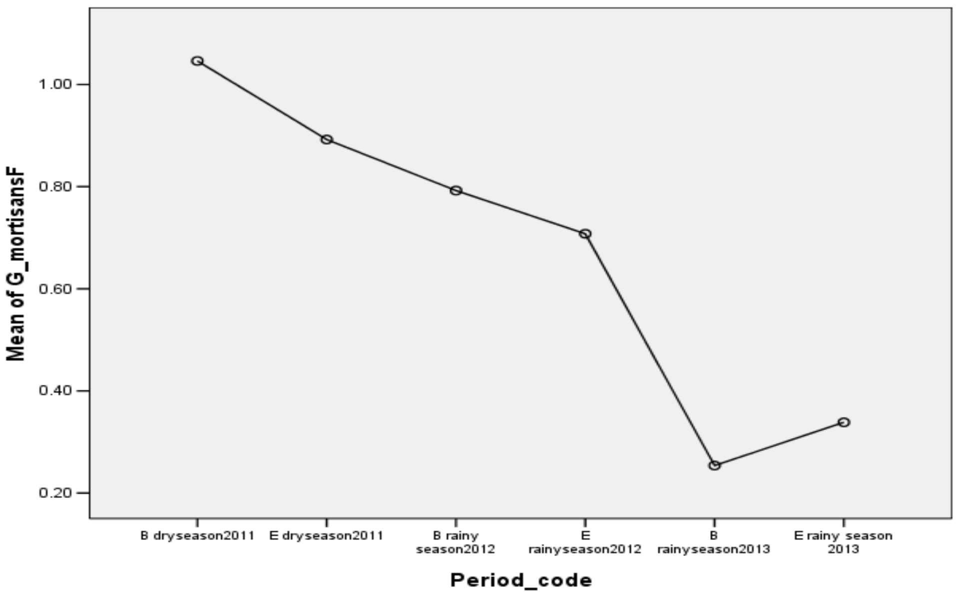

Figure 9 Density of *G. morsitans* females, according to season and deployment of screens.

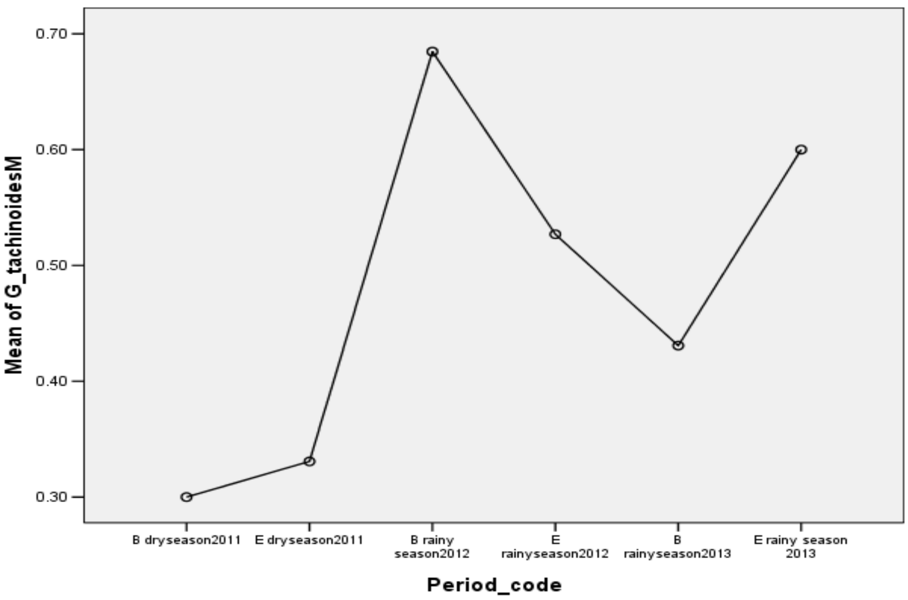

Figure 10 Density of *G. tachinoides* males, according to season and screen deployment.
B = beginning of season; E = end of season

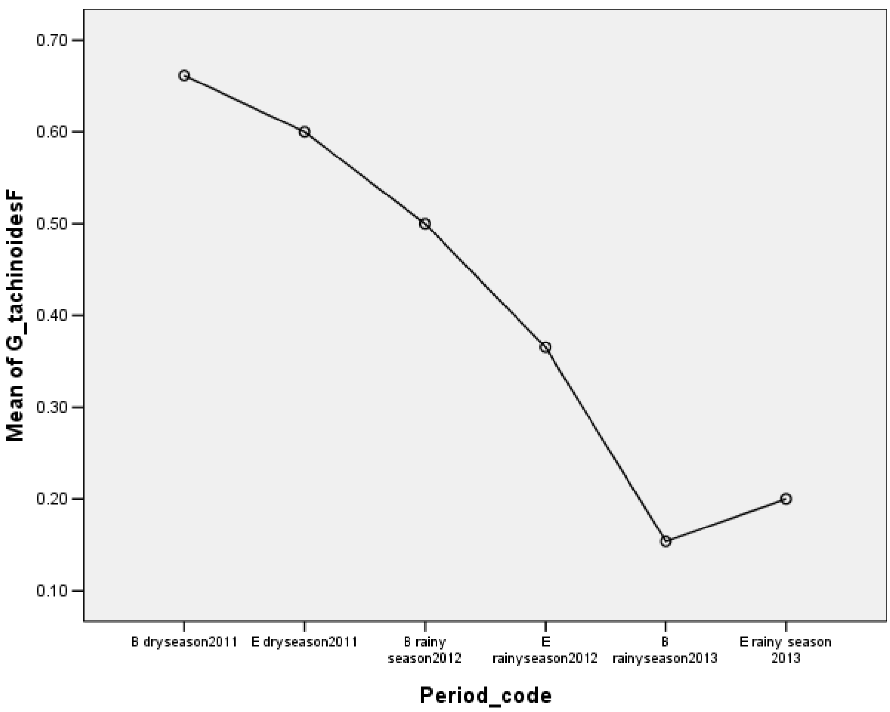

Figure 11 Apparent density of *G. tachinoides* females, according to season of trap and screen deployment.

Discussion

Pyrethroid insecticides, especially Deltamethrin, have long been considered as the insecticides of choice to impregnate odor baited targets (Courtin *et al.* [12]; Bauer *et al*. [26]). It was observed from the present survey that the apparent fly density before intervention with pyrethroid impregnated target screens was 28.93 F/T/D, which was higher than the 12.49 F/T/D obtained post intervention, with a percentage reduction of 43.17 %. The reduction effect of screens in the present study is lower than the 94.9 % reported by Bekele *et al*. [12], and the 80 % reduction reported by Courtin *et al*. [12]. The relative low rate of reduction in the present trial might have been due to the low concentration of Deltamethrin applied to the target screens, leading to a weak knockdown effect (kde) of this insecticide. Similarly, it has been observed that some screens were being destroyed by the "Mbororo" pastoralists who use the blue material to sew their dresses. Generally, the Mbororo pastoralist group, from the neighboring Central African Republic, is a stubborn one, and is never willing to listen but do what pleases them. Moreover, forestry guards patrolling around important wild reserves are often ignorant of the role of impregnated screens in the control of tsetse flies, and sometimes destroy them, as they think that these screens hinder the free circulation of wild animals as instructed by some private park owners (who refused this exercise, even after having been sensitized). For this reason, the trap/screen density in the area was reduced and, according to Muzari, [27], impregnated screens as targets could only be effective when deployed at the required densities for tsetse elimination. Based on these factors, it is clear that the present result was not unexpected. Fly dynamics data revealed that more females were captured than males in both species of *Glossina* identified. Similar results have been reported by Mulugeta *et al*. [27]; Msangi [28] showed that, in an unbiased sample, females will comprise between 70 to 80 % of the mean population, as they live longer than males. Flies captured belonged more-to the savanna than to the riverine group, throughout the study period. This is contrary to the results of Rogers and Randolph [29], whose report indicated a greater proportion of riverine than the savanna group of tsetse flies in their trial. This might be due to the fact that the Mayo Rey division is entirely covered by savanna (the habitat for *G. morsitans*) type vegetation, with only a few rivers, such as the river Bini, acting as a major site for riparian tsetse (habitat for *G. tachinoides*) biotopes. However, there was a greater savanna habitat as compared to its riverine counterpart. This reasoning permitted us to expect a higher density of *G. morsitans* as compared to riparian *G. tachinoides*. Fly density was observed to drop in the course of the dry season for the 2 species except for *G. tachinoides* females before the deployment of screens. Generally, all species witnessed a steady drop in their densities following screen deployment. A steady increase in fly numbers of both species was noticed during the rainy season, even at the time when screens were in place. This result is similar to those obtained by Mulugeta [23] and Leak [30]. This increase may be attributed to favorable habitat, food availability, and an optimal temperature and humidity for the survival of tsetse flies (Brightwell *et al*. [31]), irrespective of the presence of control tools. The increase in fly numbers at the end of the rainy season of 2013 in the presence of screens might also be due to a low rate (2 times per month) of replenishment of screens with Deltamethrin insecticide.

The deployed Deltamethrin-impregnated targets did not just play the role of re-invasion barriers as used by the Special Mission for the Eradication of Glossines (M.S.E.G.) in the area in the 1990s for tsetse fly control in Adamaoua, but had an indirect impact on trypanosomiasis incidence and cattle health. It was observed that the mean disease incidence was 26.25 % before and 14.65 % post intervention. This finding reveals that there was an incidence reduction of 55.79 %. This present finding reported low incidence post screen deployment as compared to the reports of some authors like Courtin *et al*. [12], with nil incident cases in the Boffa H.A.T focus of Guinea, and Girmay *et al*. [14] reported *T. spp* reduction from 12.14 % before to 3.61 % after control target (0.1 % Deltamethrin). Such a slow trend can be likened to a shorter time taken than the average required. Chamsa *et al*. [32] proved that, by using insecticide-impregnated odor baited targets it could take not less than 9 months to attain a marked drop in disease incidence, as well as achieve scanty fly catch. Mean weight before and after the installation of screens, as well as between seasons, showed an appreciable improvement, owing to the fact that screens reduced fly burden. This finding is in consonance with the earlier reports of two authors, who stated that weight gain steadily increase as horse fly (mechanical vector of trypanosomes) numbers decrease [33,34].

It was interesting to observe that, although results from BCT analysis portrayed a slightly higher mean incidence in the rainy season than the dry season, there was no significant difference. This result disagrees with that of Majekodunmi *et al*. [35], who rather stated that there was a significant difference in trypanosomosis prevalence according to season. Apart from improved body weight as an indicator of cattle in good health after tsetse control intervention, BCT and PCV did not show a significant difference between application periods. Also, animals were not treated with drugs before the intervention phase with screens, since barriers act on ecto-parasites in the case of tsetse, and not directly on blood dwelling trypanosomes. Intra-herd transmission through wounds resulting from fights could have contributed to mechanical transmission in the absence of tsetse flies that were already eliminated by screens. Hence, the non-significant difference in BCT containing trypanosome was expected. The non-significant difference of PCV, pre and post-deployment of screens, could be due to the fact that Bini was rich in both terrestrial and aerial pasture during the study period, which contributed to their improved nutritional status, confirming the insignificant difference in PCV following the Deltamethrin screen deployment phases. Duncan's test was employed to compare mean BCT and mean PCV with breeds and was represented graphically. It was clearly appreciated from this comparison that there was no significant difference in BCT with respect to White Fulani and Red Fulani breeds, but Gudali showed a significant difference in BCT, and also recorded the lowest positive BCT. This observation is corroborated by the results of Mbahin *et al*. [36], who found a prevalence of 5.3, 20.6, and 16.4 % for Gudali, White, and Red Fulani in Faro and Deo division. For PCV according to breed, PCVs of > 31.6 %, > 31.0 % and > 25 % were recorded for Gudali, Red, and White Fulani, respectively. There was no significant difference found between PCV of White and Red Fulani, but there was a significant difference in PCV of Gudali with other breeds. This corroborated still with the finding of Mbahin *et al*. [36] in the infested zone of the Faro and Deo Division. This decreased susceptibility to trypanosomosis may be attributed to the fact that Gudali is an indigenous breed of this region, has co-habited with vectors and the disease for several decades, and has incurred a remarkable level of tolerance compared to the Fulani cattle which visit the area only temporarily from neighboring Nigeria during transhumance in search of pasture. According to the finding of Muzari [27], targets used as barriers for re-invasion are more economical and effective when deployed at the invasion source at densities required for tsetse elimination.

The current tsetse fly intervention, which was partly community-based through sensitization, succeeded on the part of the indigenes of Bini communities, even though it was not as expected because of the non-engagement of mobile pastoralists from neighbouring countries like Chad and the Central African Republic and private game reserve owners. This is in line with the report of Kovacic *et al.* [37] who reported that community-based interventions against tsetse will therefore depend on an early engagement with communities and carefully designed sensitization campaigns that reach all communities, especially those living in areas new to such interventions.

To conclude, the trypanosome species identified in the course of the trial were: *T. congolense*, *T. vivax*, and *T. brucei brucei*. Tsetse flies caught and identified were *G. morsitans submorsitans* and *G. tachinoides* of both sexes, with an overall fly catch of about 1,491 flies. Savanna group flies were captured more frequently than the riverine group. Females constituted a larger part of the flies caught as compared to males. Seasonal changes significantly affected cattle weight, but not PCV or BCT. Tsetse fly population builds up during the rainy season, resulting in a fly density boom at the beginning of the dry season as compared to the beginning and the end of the rainy season, except for the *G. tachinoides* female. Incidence peaks were observed at the end of the rainy season, which corresponded to the fly density boom period. However, deployed Deltamethrin screens brought about a tsetse density and incidence reductions of 4.17 and 55.79 %, respectively. These screens also brought about a significant improvement in cattle weight, but not in PCV and BCT. The presences of protected parks and the river Bini serve as biotopes for savanna and riparian groups of tsetse flies such as *G. morsitans* and *G. tachinoides,* respectively, which are major vectors of trypanosomosis in Bini and maintain its steady transmission. In the nearest future, measures such as integrated Pyrethroid (Deltamethrin)-impregnated screens (at high concentrations and with frequent Deltamethrin replenishment rates), coupled with an area-wide insecticide broadcast approach of Pan African Tsetse and Trypanosomosis Eradication Campaign (PATTEC) will be a better Tsetse and Trypanosomosis (T&T) knockout option along the banks of river Bini. Also, this modern approach should be sandwiched between full sensitization on control tools and complete engagement of community individuals, especially mobile pastoralists and private reserve owners, in order to achieve the goal.

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