Susceptibility of N’Dama cattle to experimental challenge and cross-species superchallenges with bloodstream forms of *Trypanosoma congolense* and *T. Vivax*

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Abstract

Susceptibility to *Trypanosoma congolense*, *T. vivax* challenge and cross species-superchallenges, and related effects on health and productivity were assessed in N’Dama cattle. Twenty-five N’Dama bulls aged 3–4 years and previously primed with trypanosome infections through natural tsetse exposure over more than one year were used. The experimental herd was divided in five groups each composed of five randomly selected animals. Group 1 was challenged with *T. congolense*, Group 2 with *T. vivax*, Group 3 was inoculated with *T. congolense* followed by a cross-superchallenge with *T. vivax*, Group 4 was inoculated with *T. vivax* followed by *T. congolense* cross-superchallenge. Animals in Group 5 were used as controls. Both *T. vivax* and *T. congolense* cross-superchallenges were carried out on Day 14 subsequent to respective initial *T. congolense* and *T. vivax* inoculations. All challenges were performed by intradermal needle inoculation of stocks of trypanosome bloodstream forms. In challenged animals (Group 1 to 4), parasitaemia profiles and packed red cell volumes (PCV) were measured for four months. Weight changes were recorded monthly and daily weight gain (DWG) computed. All cattle challenged with *T. congolense* became parasitaemic. Conversely, one animal in Group 2 and two in Group 3 never displayed patent *T. vivax* parasitaemia. Both in single (Group 1), initial (Group 3) and cross-superinoculated (Group 4) cattle higher percentage of positive blood samples and higher parasitaemia level were obtained following *T. congolense* than *T. vivax* inocula (Group 2, 3 and 4) (*P* < 0.04 or greater). Overall the pre-challenge period, PCV values and DWGs were nearly identical in the five groups. Conversely, over the post-challenge period, cattle singly, initially and cross-superinoculated with *T. congolense* (Group 1, 3 and 4) displayed lower PCV values and DWGs in comparison with both control animals (Group 5) and with singly *T. vivax* challenged cattle (Group 2) (*P* < 0.05 or greater). No difference in mean PCV levels and DWGs was found between animals in Group 2 and cattle in Group 5. It was concluded that trypanotolerant N’Dama cattle suffered more from *T. congolense* and mixed *T. congolense*
T. vivax infections, while pure T. vivax infection did not produce appreciable negative effects on their health and productivity. Therefore, considering that tsetse and trypanosomosis control campaigns are costly and are justified only when derived economic benefits exceed those of control, and also that an ample mosaic of farming systems exists in West Africa, species-specific trypanosome prevalence and relative impact should be assessed in various cattle populations and breeds differing in trypanosome susceptibility before advising any intervention. Moreover, virulence and related effects of T. congolense and T. vivax endemic stocks on health and productivity in local cattle populations should also be estimated in order to counsel appropriate economic protection measures against trypanosmosis, i.e. vector control and/or strategic use of trypanocidal drugs. ©1999 Elsevier Science B.V. All rights reserved.

Keywords: Cattle-protozoa; Trypanosoma congolense; Trypanosoma vivax; Susceptibility; Cross superchallenge

1. Introduction

Trypanosomosis severely impairs the economic efficiency of livestock industry in tsetse-infested areas of sub-Saharan Africa (Jordan, 1986). In these zones, Trypanosoma congolense, T. vivax and T. brucei brucei are the main pathogenic species encountered. In field investigations, mixed infections are often observed both in wildlife (Mattioli et al., 1990) and domestic livestock (Connor and Halliwell, 1987). Although variations in virulence between different trypanosome stocks (Dwinger et al., 1986) and clones (Roelants and Pinder, 1987) belonging to the same species is known to occur, T. congolense and T. vivax are generally considered to be more pathogenic to cattle, as assessed by their capacity to induce anaemia, depress liveweight and, eventually, cause death, than T. b. brucei (Stephen, 1970).

In The Gambia local cattle stock is composed almost exclusively of the trypanotolerant N’Dama breed (Dwinger et al., 1994). The trypanotolerant trait of this breed allows N’Dama cattle to survive and to be productive in tsetse-infested areas (Trail et al., 1993). However, field investigations carried out in Gabon (Trail et al., 1992) and in Democratic Republic of Congo (formerly Zaire) (Trail et al., 1994) reported trypanosomosis as being a pathological stress also in N’Dama cattle, as assessed by anaemia development and reduced growth, T. congolense infection having a more severe impact than T. vivax infection. The studied N’Dama populations most likely originated and/or derived from stocks imported from The Gambia and Senegal (Shaw and Hoste, 1987). Murray et al. (1981) postulated a higher degree of tolerance to T. vivax relative to T. congolense infection in Gambian N’Damas, a characteristic that might contribute to the better performance of N’Dama in comparison to zebu cattle.

Country wide epidemiological survey conducted in The Gambia found both T. congolense and T. vivax prevalences in N’Dama cattle greatly differing from one area to another (Dwinger et al., 1994), with variation of the T. congolense : T. vivax infection ratio (Leperre and Claxton, 1994; Mattioli et al., 1998). Similarly, significant variations in productivity of traditionally managed N’Dama cattle were recorded in different areas of The Gambia infested by tsetse flies (Dwinger et al., 1994). Nevertheless, although studies carried out in this country showed trypanosomosis as a pathological factor affecting health (Murray et al., 1977a) and limiting both weight gain (Agyemang et al., 1992; Dwinger et al., 1994) and
milk production (Agyemang et al., 1990) in village N’Dama stock, no critical assessment was attempted to differentiate between the effects derived from *T. congolense*, *T. vivax* and mixed infections.

This study was, therefore, designed to explore the susceptibility and the effects on health and weight gain in N’Dama cattle of single *T. congolense*, *T. vivax* infections and relative cross-species superchallenges.

2. Materials and methods

2.1. Animals

A herd of 25 N’Dama bulls, aged 3 to 4 years at the start of the study, was used. In August 1995 to the beginning of November 1996, all animals were exposed to field-tsetse challenge and experienced several trypanosome infections (Mattioli et al., 1998). In the first half of November 96, cattle were transferred from the tsetse-infested area to the Kerr Serigne station of the International Trypanotolerance Centre (ITC), situated on the Atlantic coast of The Gambia. At this site the tsetse challenge is zero (Dwinger et al., 1992). As these animals were from a tsetse-infested area, at the arrival at ITC station they were examined for the presence of trypanosomes using dark ground/phase contrast buffy coat method (Murray et al., 1977b). Eight of them were found parasitaemic. Both positive and negative cattle were treated intramuscularly with diminazene aceturate (Berenil, Hoechst) at a dose of 7 mg kg$^{-1}$ of body weight (bw) on 14 November 1996. Cattle were also dosed with an anthelmintic (albendazole, Albex, Chanelle, 10.5 mg kg$^{-1}$ bw per os). The subsequent week all cattle were re-examined for bloodstream-circulating trypanosomes: they were found negative. Animals remained aparasitaemic, as assessed by examination of blood samples collected weekly, until experimental trypanosome infections were performed.

2.2. Trypanosomes

*T. congolense* and *T. vivax* were isolated from naturally-infected N’Dama cattle living in the same area in which the experimental animals were previously tsetse-exposed. An earlier study indicated that *T. congolense* and *T. vivax* populations occurring in that area are pathogenic for N’Dama cattle, as assessed by overt clinical signs of trypanosomosis and mortality occurrence in animals infected by either trypanosome species (Mattioli et al., 1998). Each trypanosome isolate was passaged by syringe once in goats and prepared into stabilate (Murray et al., 1983) when both *T. congolense* and *T. vivax* parasitaemic levels, in examined jugular blood samples, reached a score of 6 (Paris et al., 1982). Stabilates were cryopreserved at $-80^\circ$C until use.

2.3. Sequence of trypanosome challenges

The experimental herd was randomly divided in five groups of five animals each. Cattle in Group 1 to 4 were intradermally inoculated with 1 ml of infected goat blood stabilate containing $10^4$ ml$^{-1}$ of motile trypanosomes (Paris et al., 1982) according to the following scheme:
### Table 1
Prepatent period (mean ± s.e.) for the six trypanosome challenges, calculated in animals which became parasitaemic, percentage of positive blood samples (number positive/number examined) and level of parasitaemia (mean ± s.e.; n = number of blood samples examined) in trypanosome mono challenged and superchallenged cattle.

<table>
<thead>
<tr>
<th>Cattle group</th>
<th>Trypanosome challenge</th>
<th>No. of animals challenged</th>
<th>No. of animals parasitaemic</th>
<th>Prepatent period (days)</th>
<th>Percentage of positive blood samples</th>
<th>Level of parasitaemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td><em>T. congolense</em></td>
<td>5</td>
<td>5</td>
<td>7.2 ± 0.8a</td>
<td>70.2ABC (144/205)</td>
<td>2.07 ± 0.11ABC (n = 205)</td>
</tr>
<tr>
<td>Group 2</td>
<td><em>T. vivax</em></td>
<td>5a</td>
<td>4</td>
<td>10.0 ± 1.4A</td>
<td>25.4aADE (52/205)</td>
<td>0.69 ± 0.09ADE (n = 205)</td>
</tr>
<tr>
<td>Group 3</td>
<td><em>T. congolense</em></td>
<td>5</td>
<td>5</td>
<td>6.4 ± 0.7bAB</td>
<td>63.4DFG (130/205)</td>
<td>1.88 ± 0.12DFG (n = 205)</td>
</tr>
<tr>
<td></td>
<td><em>T. vivax</em> superchallenge on Day 14</td>
<td>5</td>
<td>3</td>
<td>8.0 ± 2.0</td>
<td>21.7bBFH (38/175)</td>
<td>0.67 ± 0.10BFH (n = 175)</td>
</tr>
<tr>
<td>Group 4b</td>
<td><em>T. vivax</em></td>
<td>5a</td>
<td>5</td>
<td>8.8 ± 0.5BC</td>
<td>15.6abCGI (29/186)</td>
<td>0.53 ± 0.10CGI (n = 186)</td>
</tr>
<tr>
<td></td>
<td><em>T. congolense</em> superchallenge on Day 14</td>
<td>5</td>
<td>5</td>
<td>10.4 ± 0.4abC</td>
<td>62.8EH (98/156)</td>
<td>1.76 ± 0.12EH (n = 156)</td>
</tr>
</tbody>
</table>

* Three animals in Group 2 and one in Group 4 found aparasitaemic for *T. vivax* 15 days after initial challenge were re-challenged intradermally.

b One animal was treated on Day p.i. 54. From that day it was excluded from analysis. Small letters: within trypanosome species comparison; capital letters: between trypanosome species comparison. Means in the same column which have the same letter are significantly different (P < 0.05 or greater).
27 February 1997 (Day 0); animals in Groups 1 and 3 were infected with *T. congolense*, those in Groups 2 and 4 with *T. vivax*. Each inoculated dose was equally distributed over three areas on the flank. On 13 March 1997 (Day 14), animals in Group 3 and those in Group 4 were superinfected with *T. vivax* and *T. congolense*, respectively. The same day, animals previously challenged and found aparasitaemic (Table 1) were rechallenged using the same trypanosome stabilate as for the primary challenge. Micro-organism concentration per inoculating dose and technique used were similar to the initial experimental challenge. Cattle in Group 5 were used as uninfected control. In order to avoid mechanical transmission of *T. vivax* (Nawathe et al., 1988), one week prior to initial infection and during the entire post-challenge period, all experimental animals were maintained in a fly-proof stable previously treated with insecticide. Throughout the study period, each animal was fed with 4 kg of groundnut hay and supplemented with 1 kg of concentrate composed of equal parts of groundnut cake and rice bran. Cattle had free access to salt-licks and water. During feeding time, there was no feed refuse in any of the experimental animal.

2.4. Data editing, sampling techniques and traits measured

In text and graphics, day numbers of the study period refer to days preceding (pre-challenge) and subsequent (post-challenge) initial experimental *T. congolense* (Groups 1 and 3) and *T. vivax* (Groups 2 and 4) challenges, considering the day of diminazene aceturate administration (14 November 1996) prior to initial trypanosomal challenges as the start of the study period (Day 105). During the pre-challenge period, samples of jugular blood were collected weekly in ethylenediamine tetra-acetic acid vacuum tubes. From Day 0 to 30, blood samples were collected every other day, subsequently twice a week until Day 119 (24 June 1997), when all trypanosome-challenged animals were successfully treated with a dose of diminazene aceturate. In blood samples, packed red cell volume (PCV) was measured by micro-haematocrit centrifugation, buffy-coat zone was microscopically examined for trypanosomes (Murray et al., 1977b) and level of parasitaemia assessed (Paris et al., 1982). As earlier experiences showed that death could occur in trypanosome-infected cattle if PCV value falls to 15% or less (Paling et al., 1991b), any animal with that PCV level or lower was treated with diminazene aceturate. Weights were recorded monthly from Day 91; the last record was on Day 119.

2.5. Statistical analysis

The main purpose of the present study was to compare the effects of *T. congolense*, *T. vivax* and relative cross-infections on health and productivity of Gambian N’Dama cattle. The occurrence of anaemia and weight loss in cattle infected with trypanosomes is well documented. Therefore, in order to avoid redundancy with already largely available information, the statistical analysis (analysis of variance (ANOVA)) was essentially performed to identify differences between trypanosome-challenged cattle groups in mean PCV values and daily weight gains (DWGs) calculated both overall the pre and post-initial challenged periods. For each animal, DWG was computed by regression of monthly weight on time. In the analysis of PCV and DWG over the post-inoculation period, contrasts between groups were tested if the factor ‘infection’ was significant. ANOVA was also employed to com-
pare differences in mean intervals of elapsing parasitaemia and parasitaemia levels both within and between trypanosome species following respective challenges. *T. vivax* challenges which did not produce detectable parasitaemia were excluded from this analysis (Table 1). Overall percentages of positive blood samples, calculated from the inoculation day of each experimental infection, were compared using the Chi-square test. Any animal which required trypanocidal treatment during the post-infection period was omitted from analysis from the day of drug administration. Statistical significance was alpha 0.05 or greater.

3. Results

Susceptibility to trypanosome infections in cattle was assessed by measuring prepatent intervals, percentage of positive blood samples, parasitaemia levels, PCV values and DWGs.

3.1. Parasitological findings

All cattle challenged with *T. congolense* (Group 1, 3 and 4) became parasitaemically positive within 4–12 days after inoculation. Conversely, three animals in Group 2 and one in Group 4 were found aparasitaemic 15 days after the initial *T. vivax* challenge. Rechallenge with the same *T. vivax* stabilate did infected two animals in Group 2 and that in Group 4. However, these animals showed patent *T. vivax* parasitaemia only in 4, 2 and 2 occasions, respectively. One animal in Group 2 rechallenged with *T. vivax* remained constantly aparasitaemic. In addition, two animals initially challenged with *T. congolense* (Group 3) and displaying patent parasitaemia never emerged parasitaemic for *T. vivax* after superchallenge (Table 1). Only one *T. congolense* superinfected N’Dama in Group 4 required a trypanocidal treatment on Day 54. On that day, the animal was positive for *T. congolense* but negative for *T. vivax*; its PCV was 14%. Following treatment, this animal became and remained parasitologically negative for both trypanosome species and PCV gradually recovered.

Within the same trypanosome species, mean elapsing time of *T. congolense* infections, from respective challenges, was significantly shorter in animals in Group 1 and 3 than in those receiving initial *T. vivax* inoculum (Group 4) (Group 1 vs Group 4, \( F = 12.8; \ P < 0.008 \); Group 3 vs Group 4, \( F = 22.2; \ P < 0.002 \)). Conversely, there was no difference in mean time to elapse of *T. vivax* infections between animals in Groups 2, 3 and 4. In the same cattle groups, longer prepatent periods of *T. vivax* in comparison with *T. congolense* infections were observed (Group 2 vs Group 3, \( F = 5.7; \ P < 0.05 \); Group 3 vs Group 4, \( F = 7.2; \ P < 0.03 \); within Group 4, \( F = 6.4; \ P < 0.04 \)), whereas in singly infected animals, i.e. Groups 1 and 2, mean prepatent interval of *T. congolense* did not differ from that of *T. vivax* (Group 1 vs Group 2, \( F = 3.3; \ n.s. \)) (Table 1).

Parasitaemic profiles of *T. congolense* infections were similar in the respective challenged groups (Group 1, 3 and 4). Peaks of parasitaemia were seen 8 days after respective challenges. Subsequently, mean parasitaemias decreased to lower levels. From Day 64, animals in the three groups displayed transient infection and lower number of trypanosomes were detectable in peripheral blood (Fig. 1). Parasitaemic peaks of *T. vivax* were observed 16–18 days after challenge both in singly (Group 2) and superchallenged (Groups 3 and 4) an-
Fig. 1. Mean parasitaemia score for *T. congolense* and *T. vivax* in N’Dama cattle (G1 = *T. congolense* only; G2 = *T. vivax* only; G3 = initial *T. congolense* and on Day 14 *T. vivax* superchallenge; G4 = initial *T. vivax* and on Day 14 *T. congolense* superchallenge).

Animals. From Day 42 after initial challenge and onwards all cattle in Group 4 were found aparasitaemic for *T. vivax*. From that day, fluctuating and scanty *T. vivax* parasitaemia was also detected in animals in Groups 2 and 3 (Fig. 1).

Overall the respective post-challenge periods, similar proportions of *T. congolense* positive samples were detected in singly (Group 1) and superchallenged cattle (Groups 3 and 4). Animals in Groups 2 and 3 showed higher percentages of *T. vivax* positive blood samples in comparison with those observed in cattle in Group 4 (Group 2 vs Group 4, \( \chi^2 = 12.7; \ P < 0.001 \); Group 3 vs Group 4, \( \chi^2 = 16.1; \ P < 0.001 \); Group 2 vs Group 3, \( \chi^2 = 0.71; \ n.s. \)). Comparison between trypanosome species showed that rates of *T. congolense* positive blood samples in Groups 1, 3 and 4 were significantly higher than those positive for *T. vivax* in Groups 2, 3 and 4 (\( P < 0.001 \) in all between group comparisons) (Table 1). Similarly, lower mean parasitaemia grades of *T. vivax* in comparison with *T. congolense* infections were recorded both in singly and superchallenged cattle (\( P < 0.04 \) or greater in all between group comparisons). Intra-trypanosome species analysis revealed that mean parasitaemia levels did not significantly differ between cattle groups (Table 1).
Prior to trypanosome infection, mean PCV values and DWGs were similar in all the five animal groups (Table 2). On the other hand, over the post-challenge period cattle in control group (Group 5) and those infected only with *T. vivax* (Group 2) displayed significantly higher overall mean PCV levels (*P* < 0.03 or greater in between group contrasts) and DWGs (*P* < 0.05 or greater in contrasts between groups) in comparison with cattle in Groups 1, 3 and 4. Additionally, the lowest mean DWGs were observed in cattle harbouring mixed trypanosome infections (Groups 3 and 4) in comparison with animals challenged only with *T. congolense* (Group 1), although the differences were not significant (Group 1 vs Group 3, *F* = 0.4; n.s.; Group 1 vs Group 4, *F* = 1.5; n.s.). The contrast between Group 2 (single *T. vivax* challenge) and Group 5 (control animals) was not significant both for mean PCV (*F* = 0.1; n.s.) and DWG (*F* = 0.03; n.s.) values (Table 2).

### 4. Discussion

N’Dama cattle primed by cyclical infection with *T. congolense* were able to impair the establishment of further cyclical challenges with homologous *T. congolense* serodemes (Paling et al., 1991a). This provides evidence for the presence of an effective anamnestic-based immune response. Moreover, although N’Dama cattle were found susceptible in acquiring heterologous tsetse-transmitted *T. congolense* serodemes, trypanosome-induced anaemia was transient and mild (Paling et al., 1991b), suggesting the capacity of this breed to develop also a resistance to the pathological effects of the infection (disease resistance). A similar phenomenon, although to a lesser extent, was also observed in Boran zebu cattle following repeated infections with different *T. vivax* stocks (Nantulya et al., 1986). Therefore, control of both parasitaemia and anaemia are considered as indicators of resistance to trypanosomal infection (Nantulya et al., 1986; Paling et al., 1991a,b).
Although antigenic variations in trypanosomes is known to occur in parasitized host permitting the micro-organism to elude, to a certain extent, host immune response (Boothroyd, 1985), a grade of stability of variable trypanosome antigens, particularly in the early stages of infection (Luckins et al., 1990), was observed in various T. congolense stocks (Luckins et al., 1986). Moreover, during prolonged infections, specific variable antigens could be expressed more than once (ILRAD, 1991). Further, Nantulya et al. (1986) reported the exhaustion of variant trypanosome antigen repertoires in cattle infected with different T. vivax stocks. These phenomena would allow the animals to develop a certain degree of immunity to subsequent trypanosome infections (Nantulya et al., 1986; Luckins et al., 1990). However, periodicity of appearance of new variant trypanosome antigens has been reported to be shorter in the course of T. congolense than T. vivax infections (Dar, 1972). Hence, animals infected with the former trypanosome species would have, consequently, less time to mount an effective immune response than cattle infected with T. vivax. Conceptually, this may lead to a more efficient control of T. vivax than T. congolense infection. Experimentally challenged cattle used in our investigation previously experienced several natural trypanosome infections over more than one year of field-tsetse exposure (Mattioli et al., 1998). During that period, T. vivax was present in, approximately, 90% of positive samples while T. congolense constituted only about 9% of the total infections detected (Mattioli et al., 1998). In the present study, N’Damas singly inoculated with T. vivax showed a better capacity to control the trypanosomal infection in comparison with singly T. congolense challenged cattle, as assessed by lower percentage of positive blood samples, lower mean parasitaemic level and higher mean PCV value in the former. Similarly, animals receiving primary T. vivax or T. congolense challenge and/or subjected to cross-superchallenge were able to control the experimentally T. vivax induced infection. It is unlikely that the initial experimental infection interfered with the establishment of the superchallenge (Morrison et al., 1982; Dwinger et al., 1989). In fact, no significant differences were observed in prepatent period, percentage of positive blood samples and level of parasitaemia between cattle challenged only with T. vivax in comparison with those initially inoculated with T. congolense and superchallenged with T. vivax. Moreover, T. vivax infection was effectively controlled also in cattle receiving T. vivax as initial challenge and T. congolense as superchallenge. It may be speculated that the used isolate of T. vivax was relatively avirulent. Alternatively, the higher parasitaemic levels, lower PCV values and derived negative effects on productivity in experimentally T. congolense inoculated animals, in comparison with T. vivax challenged cattle, may be ascribed to the absence or limited anamnestically based immune response to the former trypanosome species, as the majority of cattle previously experienced field T. vivax infections (Mattioli et al., 1998).

Associated with the ability to control T. vivax challenge, significantly higher mean weight gain was recorded in cattle inoculated solely with that trypanosome species in comparison with those animals in which T. congolense (single and/or cross-superchallenge) infections were performed. These experimental observations suggest a higher tolerance of the N’Dama breed to T. vivax in comparison to T. congolense infection and corroborate findings of field studies conducted in Gabon and Democratic Republic of Congo on the species-specific impact of trypanosomal infections on health and productivity in other N’Dama cattle populations (Trail et al., 1992, 1994). Moreover, results from this study provide further evidence that, in cattle, the ability to control parasitaemia and limit trypanosome induced anaemia
results in superior weight gain (Trail et al., 1990). Therefore, anaemia and parasitaemia controls can be recommended as reliable criteria to evaluate not only the level of trypanotolerance (Trail et al., 1993) but also the impact of trypanosomosis on cattle productivity in general.

West African traditional cattle production based on the trypanotolerant N’Dama breed appears to be economically profitable in areas infested by tsetse fly (Itty et al., 1994; Itty, 1996). It has been observed that reduced tsetse pressure, obtained through long-term fly-control campaign, diminishes mainly \textit{T. congolense} prevalence in cattle, while \textit{T. vivax} prevalence is less affected (Rowlands et al., 1996). This phenomenon was ascribed to the capacity of the latter micro-organism to be mechanically transmitted by haematophagous insects other than tsetse fly (Nawathe et al., 1988). Operational costs of vector and vector-borne disease control are elevated and intervention campaigns, aimed to improve animal health and productivity, are justified only when the derived economic benefits exceed those of control. From the present study, it is concluded that \textit{T. vivax} has a less severe impact than \textit{T. congolense} and \textit{T. congolense}/\textit{T. vivax} mixed infections in trypanotolerant N’Dama cattle in The Gambia. However, considering the existing ample mosaic of farming systems in the West African region, further investigations are needed to obtain more information on the species-specific tolerance/susceptibility and on the economic impact of trypanosomosis in different cattle breeds. Moreover, virulence and associated effects of endemic stocks of \textit{T. congolense} and \textit{T. vivax} on health and productivity of local cattle populations should also be estimated in order to counsel appropriate economic measures against trypanosomosis, i.e. vector control and/or strategic use of trypanocidal drugs.

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