Factors influencing the prevalence of trypanosomosis in Orma Boran (trypanotolerant) and Teso zebu (trypanosusceptible) cattle crosses in Teso District, western Kenya

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Abstract

The objective of this study was to determine factors associated with occurrence of trypanosomosis in the first generation (F1) crossbreds between trypanotolerant Orma Boran and trypanosusceptible Teso zebu cattle in a trypanosomosis endemic area in Teso District, western Kenya. The offspring were screened for trypanosomosis and other haemoparasites using parasitological methods. Packed cell volume (PCV), body weights and tsetse density (FTD) were also determined. Factors considered in the analysis included sex, age, body weight and season of the year. Generalized linear mixed models (GLMM) were used for multivariable analysis to account for clustering of observations at the animal level and estimate outcome variance parameters.

The overall trypanosomosis prevalence was 2.3% (n=477) probably corresponding to low FTD in the area (<1fly/trap/day). The risk of trypanosomosis infection was higher in dry than wet season (OR = 5.4) and in older than younger offspring (OR = 1.1). The variance parameters obtained indicated that variation of trypanosomosis prevalence lay only at the animal level. Intercurrent haemoparasites detected included *Anaplasma marginale, Theileria* and *Babesia* species.

Overall, the results suggested that when the tsetse density is very low, control of trypanosomosis in the Orma-Teso zebu offspring in western Kenya require targeting of individual affected animals in the dry seasons.

Key words: age, anaemia, generalized linear mixed models, parasitaemia, season, tsetse density

Introduction

Tsetse-transmitted trypanosomosis is considered to be one of the major constraints to improved livestock production in sub-Saharan Africa (SSA) (Kristjanson et al 1999). The major control options for this disease include chemoprophylaxis and chemotherapy (Peregrine 1994), management of the vector (Bauer et al 1992) and exploitation of genetic resistance exhibited by certain livestock breeds (d'Ieteren et al 1998). However, difficulties in development of an anti-infection vaccine and of sustaining tsetse control, and the increasingly reported trypanocidal drug resistance imply that greater hope in animal trypanosomosis control lies in the exploitation of trypanosomosis resistant breeds of livestock (d'Ieteren et al 1998). The latter instance involves situations where certain breeds of cattle have been found to remain relatively healthy and productive in areas where trypanosomosis occur and these include the humpless longhorn N'Dama, the Baoulé and the shorthorn Muturu in

West Africa (Murray et al 1982) and the Orma Boran in East Africa (Dolan 1998). This phenomenon, referred to as trypanotolerance, is defined as the capacity of an animal to control parasitaemia and anaemia in a trypanosomosis infection without the aid of trypanocidal drugs (Murray et al 1982). In addition, disease resistance in the trypanotolerant N'Dama cattle extends to tick-borne diseases (TBDs) (Knopf et al 2002), helminthosis (Zinsstag et al 2000) and dermatophilosis (d'Ieteren et al 1998). Similarly, susceptibility to tick infestation was reported to be lower in the trypanotolerant Orma Boran cattle relative to certain cattle breeds in Kenya (Mwangi et al 1998a). These findings suggest that potential utilization of trypanotolerant cattle could be feasible even in the occurrence of other economically important livestock diseases in trypanosomosis endemic areas.

Exploitation of the trypanotolerant Orma cattle breed was implemented by the Kenya Government through the former Kenya Trypanosomiasis Research Institute (KETRI) (now called Kenya Agricultural Research Institute-Trypanosomiasis Research Centre (KARI-TRC)) by means of regional dissemination of trypanotolerant Orma Boran sires to farmers. The purpose of the programme was to plan and implement a long-term strategy for conservation, utilization and dissemination of the Orma Boran cattle breed and evaluation of the possibility of conferring trypanotolerance to susceptible cattle through crossbreeding with the ultimate goal of controlling the impact of trypanosomosis. Two pilot trypanosomosis endemic regions identified in the project included Nguruman in Kajiado District in south west Kenya (Maichomo et al 2005) and Teso District in western Kenya.

Preliminary data in Kenya comparing Orma-Maasai crossbreds and pure Maasai zebu cattle reported higher trypanosomosis incidence (61% vs 39%) but superior body mass (164kg vs 123kg at 18 months of age), faster growth rate (72kg vs 64kg at 8 months) and better control of packed cell volume (PCV) (29.4% vs 28.4%) and this was noted particularly during the rainy season (Maichomo et al 2005). There are no other studies investigating factors that would affect prevalence of trypanosomosis in trypanotolerant cattle in East Africa. The aim of the current study was to determine the factors that affect the occurrence of trypanosomosis in Orma Boran/Teso zebu F1 crossbred calves (herein referred to as Orma-Teso zebu offspring) under natural field conditions in Teso District in western Kenya.

Materials and methods

Study area

Teso District is located in Western province of Kenya and is bordered by the Republic of Uganda to the west. The district lies between latitude 0^o 29′ and 0^o 32′ North and longitudes 34^o 01′ and 34^o 07′ East. The district's altitude ranges from 1,300m to 1500m above sea level. Most parts of the district receive between 1,270mm and 2000mm of annual rainfall whose distribution is bimodal. Temperatures for the whole district are more or less homogenous with annual mean maximum temperature ranging between 26^oC and 30^oC while the mean minimum temperature ranges between 14^oC and 22^oC (Jaetzold and Schmidt 1983). The administrative divisions (herein after referred to as villages) in the district where the offspring were reared were Chakol, Amagoro and Amukura.

Breeding program

Initially, nine Orma Boran sires selected on the basis of trypanotolerance were disseminated to nine farmers in Teso District in November 2001. The sires were managed comparably with the local Teso zebu cattle. The research team conducted an intensive awareness campaign in the local community on the presence and availability of the Orma Boran sires for crossbreeding with the local Teso zebu cattle. However, natural breeding of Teso zebu cattle was not financially charged. The service date was recorded by Orma Boran sire's owner while calving was reported to the nearby former KETRI sub-center by the dam’s owner for recruitment of the Orma-Teso zebu offspring into the study. The calves were then ear-tagged for identification and subjected to monthly surveillance of health and productivity parameters. Management of the offspring was similar to that of the other stock.

Study population

The observations used in this study belonged to 86 Orma-Teso zebu offspring born between January 2003 and June 2005 in all the villages. The observations contributed by an offspring to the study base thus varied depending on the length of time each offspring was under surveillance. Incomplete records were, however, omitted from the database leaving 584 records for all infections used in the analysis. All the Orma-Teso zebu offspring were managed by the owners without any influence from the research staff.

Screening

The Orma-Teso zebu offspring were screened monthly for trypanosomosis using buffy coat technique (BCT) (Murray et al 1977). Approximately 70µl of blood was collected by ear vein venipuncture into two heparinised microhaematocrit capillary tubes. The degree of anaemia was estimated by measuring the PCV using Hawksley microhaematocrit reader (Hawksley, Lancing, United Kingdom). Determination of trypanosome species was carried out using their motility characteristics. Offspring that were found to be positive on BCT were treated with a single dose of diminazene aceturate (Veriben®, Sanofi Kenya Ltd) at 7.0 mg/kg administered intramuscularly when their PCV values had dropped to 20% or lower (Trail et al 1991).

Giemsa-stained thin blood smears from each offspring were used for examination of tick-borne infections (TBDs) (Karanja 2005). Detection of specific haemoparasites in the blood smears was confirmatory for *Anaplasma* and *Babesia* species. Any other type of piroplasm detected (apart from *Babesia* piroplasms) was classified as theilerial piroplasm as speciation of theilerial piroplasms is difficult in an area where multiple species of *Theileria* have been recognized in cattle (Norval et al 1992). Although the Orma-Teso zebu offspring found infected were only treated when they manifested overt clinical signs and a low PCV of less than 20%, animal welfare standards and owners’ perceptions were taken into consideration when applying this protocol.

Entomological survey

During farm visits, 5 to 10 bi-conical traps were deployed in each village where the offspring were reared to determine the apparent tsetse density (Bauer et al 1992). The traps were baited with 250 ml of acetone and emptied 48 hours after deployment. Flies were identified, counted, species identified and sexed. Apparent tsetse density was then expressed as the number of flies per trap per day (FTD). Age determination of tsetse flies was based on the wing fray method (Jackson 1946). Trypanosome infection rates were determined by dissection (Lloyd and Johnson 1924).

Data management and analyses

All data were managed in Microsoft Access® database (Microsoft Corporation, USA). Statistical analyses were carried out using STATA version 9 (StataCorp 2005). The level of significance was set at 5% (2-sided).

Morbidity status due to trypanosomosis, anaplasmosis and piroplasmosis (combined Babesia and theilerial piroplasms) were the outcome variables of interest. A trypanosome infection included *Trypanosoma congolense*, *Trypanosoma vivax, Trypanosoma brucei* or mixed infection by these parasites. Explanatory variables included sex and age of the Orma-Teso zebu offspring, season of the year, village and herd. The classification of months into season depended on the number of days that received rainfall in each month: > 15 days was coded wet and < 15 days was coded dry. All calves in a particular village were sired by one bull; thus the variable 'village' and 'sire' were expected to be perfectly matched hence these variables were not included in the model simultaneously. Herd and village were offered into the model as explanatory random variables.

Descriptive analysis and testing association between PCV and both explanatory and response variables were initially conducted. These were followed by estimation of crude odds ratios (ORs) by univariable analyses. Univariable analyses considered one explanatory variable at a time against each response variable. Ordinary multivariable logistic regression models were then fitted to the data and both backward and forward variable selection process was used to build the models based on the Wald's test statistics. The data were deemed to cluster at least three levels: (i) animal-level because of repeated measures in time, (ii) herd level because of shared farm-level management system and (iii) village level because of shared ecological exposures and breeding sires. To account for this hierarchical clustering, generalized linear mixed (GLMM) models using a logit link were fitted to the data. The latter models were used to estimate the values of the parameters of the random variables (animal, herd and village) considered in the analysis.

Results

Prevalence of infections

In this study, records obtained were treated as though repeated surveys were conducted rather than those expected from a longitudinal study. A total of 89 infections comprising 11 cases of trypanosomosis, 73 of anaplasmosis and 5 of piroplasmosis (combined babesial and theilerial piroplasms) were recorded. Their respective prevalences were 2.3% (n=477), 15.3% (n=477) and 1.05% (n=474). The total number of *T. vivax* (Tv) and *T. congolense* (Tc) infections was 8 and 3 respectively giving a Tv:Tc ratio of 2.7:1.

Entomological sampling

Two tsetse fly species namely *Glossina pallidipes* and *Glossina fuscipes* were caught in the study areas in the course of the surveillance. The overall mean FTD within the three villages was less than 1/trap/day. Generally, *Glossina fuscipes* was more abundant than *Glossina pallidipes* during the wet season of April and May 2005 with FTDs of 1.3, 1.4 and 1.8 in Amukura, Amagoro and Chakol villages respectively. This observation arose possibly because majority of the traps were deployed near the streams and rivers where *Glossina fuscipes* species is often found. FTDs for *Glossina pallidipes* remained <1 throughout the course of the surveillance.

Relationship between PCV values and both explanatory and outcome variables

The mean PCV for all offspring throughout the study period was 30.1% (SD 5.74). The difference in the mean PCV values by sex and village were significant (P<0.001) but that by season was not significant (P=0.71) (Table 1).

Table 1. Relationship between PCV values and all variables in Orma-Teso zebu offspring surveillance data collected in Teso District, western Kenya, January 2003–June 2005

Variable	Level	PCV (SD)	p
Season	Wet	30.0 (5.5)	0.71
	Dry	30.2 (5.7)	
Sex	Male	29.3 (5.2)	<0.001
	Female	31.1 (6.0)	
Village	Amagoro	28.5 (4.2)	<0.001
	Kwangamor	26.5 (5.2)	
	Otimong	30.9 (5.6)	

Trypanosomosis	Positive	27.4 (5.8)	0.11
	Negative	30.1 (5.6)	
Anaplasmosis	Positive	25.6 (5.0)	<0.001
	Negative	30.9 (5.4)	
Piroplasmosis	Positive	27.4 (6.0)	0.28
	Negative	30.1 (5.6)	

The difference in PCV% between trypanosome parasitaemic and aparasitaemic offspring was not significant (P=0.11), while that between anaplasmosis parasitaemic and aparasitaemic offspring was significant (P<0.001) (Table 1). The difference in PCV% between positive and negative piroplasmosis cases was not significant (P=0.28) (Table 1).

Univariable analysis

The crude ORs from univariable logistic regression models for all response variables are shown in Tables 2 and 3 respectively.

Table 2. Prevalence of trypanosomosis and crude odds ratios (ORs) from univariate analysis of Orma-Teso zebu surveillance data collected in Teso District, western Kenya, January 2003-June 2005

Variable	**Level**	***n***	**% prevalence (95% CI[a])**	**OR[b] (95% CI)**	**p**
Sex	Male	272	2.2 [0.8, 4.7]	1.0	0.85
	Female	203	2.4 [0.8, 5.6]	1.1 [0.3, 3.7]	
Season	Wet	258	0.7 [0.1, 2.7]	1.0	0.03
	Dry	219	4.1 [1.8, 7.7]	5.5 [1.2, 25.7]	
Village	Amagoro	57	-		
	Kwangamor	67	2.9 [0.4, 10.4]	1.2 [.2, 5.6]	0.83
	Otimong	353	2.5 [1.2, 4.8]	1.00	
Age				1.1 [0.9, 1.1]	0.15
Body weight				0.9 [0.9, 1.0]	0.99

a: Confidence interval; b: Crude odds ratio

Season was the only variable that was significantly associated with the occurrence of trypanosomosis (p=0.03) (Table 2) and anaplasmosis (p=0.02) (Table 3).

Table 3. Prevalence of anaplasmosis and crude odds ratios (ORs) from univariate analysis of Orma-Teso zebu surveillance data collected in Teso District, western Kenya, January 2003-June 2005

Variable	**Level**	***n***	**% prevalence (95% CI[a])**	**OR[b] (95% CI)**	**p**
Sex	Male	273	16.5 [12.3, 21.4]	1.0	0.26
	Female	203	12.8 [8.5, 18.2]	0.7 (0.4, 1.3]	
Season	Wet	258	11.6 [8.0, 16.2]	1.0	0.02
	Dry	219	19.6 [14.6, 25.5]	1.9 [1.1, 3.1]	
Village	Amagoro	57	26.3 [15.5, 39.7]	3.0 [1.5, 5.8]	0.45
	Kwangamor	67	29.9 [19.2, 42.3]	3.5 [1.9, 6.6]	
	Otimong	353	10.8 [7.7, 14.5]	1.0	
Age				1.0 [0.9, 1.0]	0.19
Body weight				1.0 [0.9, 1.0]	0.34

a: Confidence interval; b: Crude odds ratio; c: body weight.

Respectively, the prevalences of trypanosomosis and anaplasmosis were 5.5 and 2 times higher in the dry than the wet season (Tables 2 and 3). None of the variables were significantly associated with piroplasmosis cases (data not shown).

Multivariable analysis

All variables obtained through univariable analysis, despite their levels of significance, were used to build multivariable models so as to compare the outputs from univariate and multivariable models. In the ordinary multivariable models, the prevalence of trypanosomosis was significantly associated with season (p=0.04) and age (p=0.03) (Table 4).

Table 4. Multivariable logistic models (before accounting for clustering) for all response variables from Orma-Teso zebu surveillance data collected in Teso district, western Kenya, January 2003-June 2005

Variable	Levels	Trypanosomosis		Anaplasmosis		All response variables combined	
		OR[a] (95%CI[b])	p	OR[a] (95%CI[b])	p	OR[a] (95%CI[b])	p
Sex	Male	1.0	0.91	1.0	0.87	1.0	0.61
	Female	1.1 [0.3, 3.7]		0.9 [0.5, 1.7]		0.9 [0.5, 1.5]	
Season	Wet	1.0	0.04	1.0	0.03	1.0	0.03
	Dry	5.2 [1.1, 24.9]		1.9 [1.1, 3.3]		1.8 [1.1, 3.0]	
Village	Amagoro	-		2.2 [0.9, 4.9]	0.07	1.6 [0.7, 3.7]	0.24
	Kwangamor	1.1 [0.2, 5.4]	0.94	2.8 [1.4, 5.8]	0.01	2.5 [1.2, 5.0]	0.01
	Otimong	1.0		1.0		1.0	
Age		1.1 [1.0, 1.3]	0.03	1.0 [0.9, 1.1]	0.73	1.0 [0.9, 1.1]	0.39
BWT[c]		0.9 [0.9, 1.0]	0.18	0.9 [0.9, 1.0]	0.81	0.9 [0.9, 1.0]	0.59
lnL[d]		-45.09		-168.12		-186.6	
Obs.[e]		399		444		444	
LR χ^2 [f]		10.52		15.43		13.76	
P> LRχ^2		0.05		0.02		0.03	

a: Adjusted odds ratio; b: Confidence interval; c: body weight; d: log likelihood value; e: number of observations; f: Likelihood ratio chi square value.

The prevalence of anaplasmosis on the other hand was significantly associated with season (p=0.03) and village (Table 4). Dry season (OR=5.2) and offspring being older (OR=1.1) were associated with higher prevalence of trypanosomosis than wet season and being young. Only season was significantly associated with piroplasmosis (data not shown). Orma-Teso zebu offspring in Kwangamor village were 2.5 times more likely to get infected by all of the parasites studied compared to those from Otimong village (Table 4).

Upon accounting for clustering by use of GLMMs, the outputs obtained were similar to those from ordinary multivariable logistic regression models. When all infections were combined under GLMMs, season and village were significant, with offspring having increased the odds of experiencing all of the infections studied during the dry season (OR=1.9) than the wet season (Table 5).

Table 5. Generalized linear and latent mixed models (GLLAM) (accounting for clustering) for all response variables from Orma-Teso zebu offspring surveillance data collected in Teso district, western Kenya, January 2003-June 2005

Variable	Levels	Trypanosomosis		Anaplasmosis		All response variables combined	
		OR[a] (95%CI[b])	p	OR[a] (95%CI[b])	p	OR[a] (95%CI[b])	p
Sex	Male	1.0	0.73	1.0	0.71	1.0	0.56
	Female	1.3 (0.3, 5.1)		0.9 (0.4, 1.7)		0.8 (0.5, 1.5)	

Season	Wet	1.0	0.04	1.0	0.02	1.0	0.02
	Dry	5.4 (1.1, 25.9)		1.9 (1.1, 3.6)		1.9 (1.1, 3.2)	
Age		1.1 (1.0, 1.3)	0.04	1.0 (0.9, 1.1)	0.62	1.0 (0.9, 1.1)	0.33
BWT[c]		0.9 (0.9, 1.0)	0.15	0.9 (0.9, 1.0)	0.79	0.9 (0.9, 1.0)	0.53
Variance	Animal	0.33 (s.e[f]. 1.21)		0.44 (s.e[f] 0.4)		0.21 (s.e[f] 0.29)	
	Herd	0.00		0.00		0.00	
	Village	0.00		0.12 (s.e[f] 0.17)		0.07 (s.e[f] 0.14)	
lnL[d]		-45.99		-170.34		-188.93	
Obs.[e]		399		444		444	

a: Adjusted odds ratio; b: Confidence interval; c: body weight; d: log likelihood value; e: number of observations; f: standard error.

Generalized linear mixed models gave variance estimates at the animal, herd and village levels. There was higher variance in the prevalence of all the infections at the animal-level (Table 5).

Discussion

The low trypanosomosis prevalence in the Orma-Teso zebu offspring reported in this study (2.3%) is comparable to that reported in the Orma-Maasai zebu crosses (3%) though the latter were maintained in a pastoral production system (Maichomo et al 2005). However, this prevalence was relatively lower than that reported for Teso zebu counterparts (2 to 10%) in the same study area and period (Matete 2002, KETRI unpublished data; Gachohi 2005, KARI-TRC unpublished data). In the neighbouring Busia District, the overall trypanosome prevalence in zebu cattle was reported to be 4.7% (Karanja 2005). The low prevalence in the Orma-Teso zebu offspring could most likely be attributed to the low tsetse density in the area (<1fly/trap/day), confinement of the calves around homesteads leading to lower tsetse challenge, or low disease risk due to massive vector control efforts by a regional European Union-led project, “Farming in Tsetse Controlled Areas, FITCA” (Karanja 2005) prior to the study period. This could also have resulted from management of disease by the farmers as trypanocides were readily accessible in this area. Although there is evidence of less susceptibility of Orma Boran to trypanosomosis than other zebu ecotypes as judged by the significantly lower incidence of infection among other factors (Mwangi et al 1998b), this is a subject of on-going research.

Development of anaemia is a common consequence of trypanosomosis (Naessens et al 2003), yet there was no significant difference in PCV values between trypanosomal parasitaemic and non-parasitaemic Orma-Teso zebu offspring in this study. This appeared to confirm observations that there is no strong association between control of parasitaemia and anaemia in trypanotolerant animals (Paling et al 1991; Naessens et al 2002). In addition, this lack of difference in PCV values could have been due to better control of anaemia by the infected Orma-Teso zebu offspring. Control of anaemia is known to be a strong indicator of trypanotolerance (Naessens et al 2002). Indeed, the repeated monthly measurements of PCV over time confirmed the capability of the offspring to maintain their PCV values despite their infection status. Previous field studies have indicated that control of anaemia (but not parasitaemia) has a significant degree of heritability (Trail et al 1991). It would be interesting to find out heritability estimates of control of anaemia in crosses between trypanotolerant and trypanosusceptible cattle in well-structured genetic studies.

Season in this study was a significant predictor with dry season being associated with higher trypanosomosis prevalence. Comparison with other studies reveals that this factor primarily depends on the characteristics of the production system applied. In western Kenya, the dominant farming system is traditional mixed crop-livestock system whereby during the wet season, cattle are mostly corralled and/or grazed near the homesteads away from the crops. In the dry season, cattle are allowed to roam freely further in the fields for grazing particularly along streams, rivers, marshy swamps and other watering points often entering the riverine tsetse-infested areas common in this region (Ford and Katondo 1977). Similar higher prevalence was reported during the dry season than wet season for trypanotolerant cattle in a sedentary farming system in Nigeria (Ogunsanmi et al 2000, unpublished data) and Ghana (Mahama et al 2004). In semi-arid areas of Kenya where absolute extensive grazing is applied, the force of trypanosomosis infection was reported to increase during the wet season in trypanotolerant cattle and their crosses probably because of unrestricted grazing patterns during the wet season (Bett et al 2004; Maichomo et al 2005). This factor underpins the importance of farming systems in influencing the challenge to which livestock are subjected and this is central to the epidemiology and planning of the trypanosomosis control particularly in regions and production systems where dissemination and breeding of trypanotolerant breeds of cattle are earmarked.

Increasing age in this study was associated with increased trypanosomosis prevalence. Young Orma Boran calves generally appear to be more resistant to trypanosomosis than older animals (Dolan 1998). Similar patterns, though based on serology, have been observed in earlier studies in Burkina Faso (Desquesnes et al 1999) and Ghana (Mahama et al 2004) involving trypanotolerant cattle. As differences in trypanosomosis prevalence across ages appear to be influenced by livestock management systems (Bett et al 2004), further research is required on interaction between age and the different livestock management systems where trypanotolerant cattle breeding programmes are targeted.

To take the clustered structure of the data into account, this study applied multilevel modeling techniques. Multilevel models are useful in estimating the contribution of the various levels of cattle population organization to the total variance of an outcome. In this manner, levels which account for a large amount of variability (high-risk levels) can be identified and targeted with the expectation that interventions at that level will have the greatest impact on outcome (Dohoo et al 2003). In this study, it was clear from the analysis that most of the variation in trypanosomosis and TBDs prevalence lay at the animal-level which could have arisen from non-additive genetic effects and/or non-genetic effects (Evans et al 1999) particularly the maternal effect variance as almost the entire Orma-Teso zebu offspring were from different dams. The large animal-level variability would indicate that interventions targeted at the individual animal would be expected to have the greatest impact on prevalence. Lack of variation both at the herd- and village-level in trypanosomosis prevalence could have been influenced by the massive vector control efforts by the FITCA project (Karanja 2005) prior to the study period. This was supported by the low density of tsetse flies in all the villages where the Orma-zebu offspring were located and further suggested that at very low tsetse density, trypanosomosis incidence varied from animal to animal. On the other hand, there was small proportion of variation detected at the village level both in the ‘anaplasmosis model’ (TBD) (21%) and ‘all response variables combined model’ (mixed trypanosomosis and TBDs) (25%). The latter finding most likely reflected the widely recognized ecological differences in which the climatic suitability for tick vectors varies over small geographic areas (Norval et al 1992).

Conclusions and recommendations

- Risk of trypanosomosis was higher in individual animals during dry seasons under very low tsetse density for the Orma-Teso Zebu offspring in the western Kenya region

- Presence of other infections which may lead to concurrent infections need to be integrated in breeding programmes for trypanosomosis resistance not only to sustain trypanotolerance stability but also to consider ecological distribution of other important pathogens prevailing in an area.

- Genetic and non-genetic factors that may have an impact on crossbreeding programmes involving trypanotolerant and trypanosusceptible cattle breeds need to be investigated by use of a quantitative approach in well-structured longitudinal and production-system studies in which the necessary identification and quantification of environmental and genetic effects are possible.

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