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ORIGINAL RESEARCH

Response of Nkedi Zebu and Ankole cattle to tick infestation and natural tick-borne, helminth and trypanosome infections in Uganda

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Abstract A cross-sectional study was conducted in Soroti district of Uganda to establish important traits of Nkedi Zebu and Ankole cattle regarding their production performance responses to natural infections of trypanosomes, gastrointestinal nematodes, *Theileria parva, Babesia bigemina*, *Anaplasma marginale* and tick infestations. Over four visits between October 2006 to August 2007, tick counts were performed and blood, faecal samples and sera were collected from the Nkedi Zebu (295) and Ankole (165) cattle from 86 herds in six locations per visit. Low parasitological prevalence of trypanosome infection (<6%) and high prevalence of gastrointestinal nematode infections (>30%) with low faecal egg counts (110–300 eggs per gramme (EPG)) were observed in the Nkedi Zebu and Ankole cattle. Both breeds had high, moderate and low mean counts of *Rhipicephalus appendiculatus* (18.0–24.0), *Rhipecephalus (Boophilus) decoloratus* (3.6–10.3) and *Amblyomma variegatum* ticks (1.7–4.3), respectively. In addition, both breeds had similar mean packed cell volumes (26.4–31.2) and a similar percentage of animals were anaemic (14.5–36.6%). The Nkedi Zebu cattle further had higher mean optical density (OD) values for antibodies against *T. parva* (1.093–1.445) and *A. marginale* infections (0.573–0.583), and significantly ($P<0.001$) higher mean OD values of antibodies against *B. bigemina* infections (1.07–2.175) than the Ankole cattle: *T. parva* (1.030–1.302); *A. marginale* (0.442–0.603) and *B. bigemina* infections (0.863–2.154). The Ankole cows produced significantly more ($P<0.001$) milk per day (2.68 L) than the Nkedi Zebu cows (1.98 L), and the Ankole oxen had significantly higher ($P<0.05$) draught power output (2.57 days/acre) than the Nkedi Zebu oxen (2.93 days/acre). Liveweights of calves aged 0–12 months of both breeds were comparable, suggesting that the Nkedi Zebu and Ankole cattle under similar disease challenge exhibited similar growth rates. In conclusion, the Nkedi Zebu cattle seem to possess a higher degree of disease resistance against endemic parasitic diseases, while the Ankole cattle seem to possess a moderate degree of disease resistance coupled with a moderate production potential.

Keywords Cattle · Breed · Disease response · Production performance · Uganda

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Introduction

Declining biodiversity in poor countries and likely extinction of indigenous breeds without much attention being paid to identifying undiscovered genetic advantages they possess has aroused concern (Rice 2008). United Nations Food and Agriculture Organisation recently reported that at least 20% of the world's estimated 7,600 livestock breeds are in danger of extinction, leading to a potential 'meltdown' in global genetic diversity (FAO 2006).

Nkedi Zebu (*Bos indicus*) and Ankole (*Bos taurus indicus*) breeds of cattle in Uganda, products of centuries of selection for traits adapted to harsh conditions, are increasing being replaced by more productive exotic dairy breeds (Rege 1999). Exotic breeds easily succumb to the overwhelming disease challenge to which indigenous breeds are adapted. Disease resistance is arguably one of

the important traits possessed by these indigenous breeds and is an important attribute of livestock in low-input livestock production systems (Gibson and Bishop 2005). Such traits if identified are useful in breed improvement programs involving crossbreeding of productive exotic breeds with indigenous breeds.

Trypanosomosis, helminthosis and tick-borne diseases are the major endemic diseases affecting cattle health and productivity in most sub-Saharan African countries. Variation in susceptibility to trypanosomosis exists among N'Dama and West African Shorthorn (Stewart 1951; Chandler 1958; Murray et al. 1981), and among Orma Boran and Maasai Zebu (Njogu et al. 1985; Ismael et al. 1985; Mwangi et al. 1998a). Recent studies suggest that there exists variation in susceptibility to trypanosomosis among Ethiopian cattle breeds, with the Sheko breed being significantly less susceptible than Abigar, Horro and Gurage (Lemecha et al. 2006). Field and anecdotal evidence seems to suggest that there exist differences in susceptibility to trypanosomosis between the Nkedi Zebu and Ankole breeds of cattle in Uganda (Magona et al. 2004).

Variation in susceptibility to helminth infection has been reported between Zebu, Boran and Sahiwal breeds in Kenya, especially regarding fasciolosis (Bitakaramire 1973). Other studies revealed that malnutrition and concurrent disease may impair host resistance against helminth infections, resulting in higher worm burdens (Kaufmann and Pfister 1990; Kaufmann et al. 1992; Waruiru et al. 1998). In Uganda, variation in susceptibility to gastrointestinal nematode infections was observed among the Nkedi Zebu, Sahiwal and Friesian cattle under natural challenge (Magona and Mayende 2002).

Breed-related differences in susceptibility to tick-borne diseases have been reported between the Zebu and crossbred cattle (Jacobsen 1983). In Zanzibar, a higher *Theileria parva*-induced mortality rate (14%) and a lower recovery rate (57%) were observed in crossbred calves as compared with the Zebu calves: mortality rate, 4.2% and recovery rate 90% (Jacobsen 1983). Mortality following experimental infection with *T. parva* was found to be higher in the crossbreds (64%) than in the Ankole cattle (32%) (Paling et al. 1991). Differences in breed susceptibility to bovine anaplasmosis has been observed elsewhere, with exotic breeds being more susceptible to anaplasmosis than indigenous cattle breeds (Ajayi et al. 1982) and clinical signs of anaplasmosis were milder in Zebu cattle than in exotic crossbred cattle (Latif et al. 1995). Elsewhere, Kenana breed of cattle in Sudan was reported to be less susceptible to *T. annulata* infection than Friesian cattle (Bakheit and Latif 2005), a difference attributed to Kenana cattle having the ability to limit multiplication of macroschizonts.

Variation in resistance to tick infestation among several indigenous breeds of cattle in Africa has been reported amongst: Zebu in Kenya (Latif et al. 1991a, b); Meru, Mbullu, Iringa red and crossbreds in Tanzania (Wambura et al. 1998), Gobra Zebu and N'Dama cattle in The Gambia (Mattioli et al. 1998); Maasai Zebu, Orma Boran and Galana Boran in Kenya (Mwangi et al. 1998b), and Horro, Guraghe, Sheko and Abigar cattle in Ethiopia (Feleke et al. 2007).

Given ongoing dairy development projects in Uganda coupled with restocking in areas once affected by civil strife that tend to favour exotic cattle over indigenous breeds, attempts are being made to establish and document undiscovered important traits of the Nkedi Zebu and Ankole cattle regarding their responses to trypanosome infections, gastrointestinal nematode infections, *T. parva* infections, *B. bigemina* infections, *A. marginale* infections and tick infestations under natural challenge in respect to their production performance.

Materials and methods

Study area

The study was carried out in Soroti district in eastern Uganda (Fig. 1) in the villages of Akumoi, Aswii, Osamito, Kamod, Opungure and Okokoma, situated on the eastern shores of Lake Kyoga. Selection of the study area was based on previous reports (Magona and Mayende 2002; Magona et al. 2004) coupled with the availability of either pure or mixed herds of Nkedi Zebu and Ankole cattle grazing under similar tsetse, tick and worm challenge.

The main vegetation type in the study area is savannah grassland. The area receives 1,200–1,500 mm of rainfall annually, which is bimodal in distribution. There are two wet seasons (March to June and September to November) and two dry seasons (December to February and July to August). The daily mean minimum temperature is 15°C and mean maximum is 27°C.

Peasant farmers in the study area practise crop production integrated with livestock keeping. Cattle are kept under traditional communal grazing management and are either tethered or grazed on communal pastures during the day and tied up around homesteads or kept in bomas at night (Magona et al. 2008).

Exposure to tsetse flies, ticks and GIT larvae

Soroti district is infested with the tsetse species, *Glossina fuscipes fuscipes* (Magona et al. 2004) that transmits *Trypanosoma brucei brucei*, *Trypanosoma brucei rhode-*

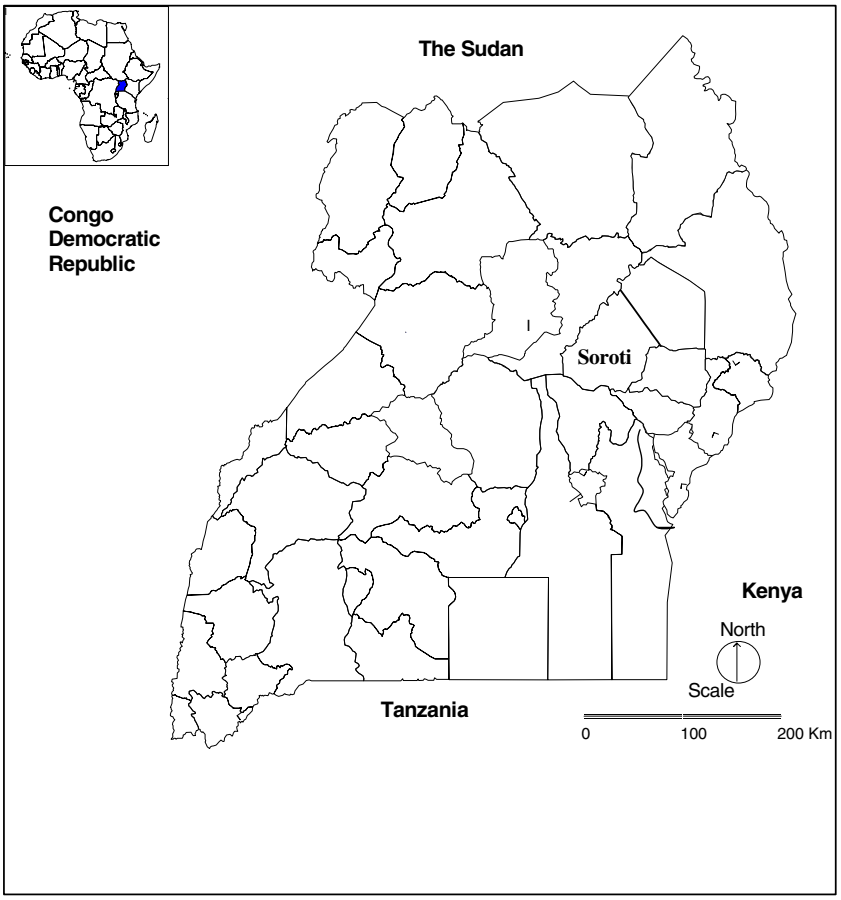

Fig. 1 Map of Uganda showing the location of Soroti district in Uganda, the study area, 2007

siense, *Trypanosoma congolense* and *Trypanosoma vivax*. *Rhipicephalus appendiculatus*, *Rhipicephalus evertsi evertsi*, *Rhipicephalus* (*Boophilus) decoloratus* and *Amblyomma variegatum* are the major tick species of economic importance that occur in the study area (Okello-Onen et al. 1999), which transmit *T. parva*, *A. marginale*, *B. bigemina* and *Cowdria ruminantium*, respectively. Climatic conditions in the area favoured continuous survival of gastrointestinal nematode larvae on pasture, while contamination of communal pastures is maintained the year round by sharing of pastures by cattle of all ages belonging to different herds (Magona and Mayende 2002).

Sampling

A sample size of at least 384 cattle was required per study visit based on an estimated prevalence of 50% and a 95% confidence interval (CI) at a 5% desired precision. The sample size was calculated using the formula $n = 1.96^2\ P\ (1\text{-}P)/d^2$ derived from Thrusfield (1995) with $P = 0.5$ and $d = 0.05$.

Sampling visits were conducted in study villages on four occasions: (1) in October 2006 (second wet season), (2) December 2006 (first dry season), (3) June 2007 (first wet season) and (4) August 2007 (second dry season). During the visits, blood, faecal samples and sera were collected from a minimum of 384 cattle randomly selected from all herds presented by the farmers at designated sites following a systematic sampling strategy. Samples were taken from every second animal of a given herd following placement of all animals of that herd in a crush. For each animal examined its breed, age and sex were recorded. Although, sampling of animals from the same herds during the four visits was desirable, not all farmers willingly presented their animals for sampling. Hence different herds were sampled during the four visits.

Adult ticks on one side of the body of each individual animal sampled were counted and tick species identified on the host. Tick data for each individual animal were recorded against the identification number of the respective animal.

Veterinary assistants, trained to diploma-level in veterinary science, were dispatched to study villages on home-to-home visits of households belonging to cattle owners to record the daily milk yield obtained from cows of respective breeds and draught power output of oxen of respective breeds. Daily milk yield was measured in litres by Veterinary assistants to

ascertain the quantity obtained from cows of either the Nkedi Zebu or Ankole breed. Draught power output was measured by observing the number of days taken by a team of four oxen of either the Nkedi Zebu or Ankole breed to plough an acre of land. As a norm in Soroti district, a team of four oxen ploughs for 4 h a day on average to enable oxen have enough grazing time to replenish depleted energy. Body liveweight of all animals aged 0–6 and 7–12 months was estimated by measuring the girth width of each animal using a tape weigh band (Webo-Denmark) adjusted for different breeds.

Diagnostic procedure

Blood samples were examined for trypanosomes using the buffy coat technique (Murray et al. 1977) and the haematocrit centrifugation technique (Woo 1969). In addition, packed cell volume (PCV) was measured for each blood sample using a haematocrit reader (Hawksley, Lancing, UK). Faecal samples were examined for nematode eggs using the McMaster method accurate to 50 eggs per gramme of faeces as described by Hansen and Perry (1994).

Sera were screened for antibodies against *T. parva, A. marginale* and *B. bigemina* infections using Svanovir Ab-*T. parva*, Ab-*B. bigemina* and Ab-*A. marginale* ELISA kits (Svanova, Biotech AB Uppsala, Sweden), performed according to manufacturer's instructions

Data analysis

Data analysis was performed using the statistical package Minitab® 15.1.1.0 (Minitab Inc., Pennsylvania, USA). Faecal egg counts were transformed to log10 (count+50) to normalise the distribution before analysis. In addition, analysis of tick counts was carried out after logarithmic transformation of data in order to stabilize the variances. Multivariable analysis was performed to compare PCV values, faecal egg counts, optical densities (OD) of antibody against *T. parva*, B. *bigemina* and *A. marginale* infections, and counts of respective tick species of the Nkedi Zebu cattle to those of the Ankole cattle. Likewise, multivariable binary logistic regression was performed to compare disease prevalence rates of the Nkedi Zebu cattle to those of the Ankole cattle. Performance data including daily milk production, draught power output and liveweight were compared between the Nkedi Zebu and Ankole cattle using the Student's *t* test.

General linear regression was performed to establish the influence of herd management, herd size, sampling site, age, animal gender and season on respective parameters of the Nkedi Zebu and Ankole cattle. All variables were included in one model and a backward procedure to eliminate non-significant variables was performed. The 5% level of significance was used throughout the analysis.

Results

Ratio and distribution of Nkedi Zebu and Ankole cattle at herd level

As shown in Table 1, a few herds presented for screening had only Nkedi Zebu cattle while others had only Ankole cattle but the majority of the herds were mixed. The number of herds presented for screening ranged from 48 to 110 and the mean herd size (±95% CI) ranged from 8.27±1.84 to 9.46±2.45 (Table 1). Ankole cattle constituted between 28% and 37% of the cattle sampled during the study visits. Sampling of different herds over visits as a result of farmers' unwillingness to present the same herds during all visits led to large variation in breed ratio between visits. Farmers' response to sampling was generally good over the four visits; however, it was poor during the third visit because farmers were preoccupied with crop cultivation, leading to an animal turn-up for the sampling of less than the minimum 384.

Table 1 Number and distribution of herds of Nkedi Zebu and Ankole cattle during the study in Soroti district, Uganda, 2007

Visit	No. of herds				Mean herd size (±95% CI)	No. of cattle	Ankole/Nkedi Zebu
	Total	Ankole only	Nkedi Zebu only	Mixed			
1	110	19	31	60	9.46±2.45	577	189:388
2	105	13	41	51	9.43±2.89	531	148:383
3	48	8	15	25	8.43±2.93	297	111:186
4	81	17	20	44	8.27±1.84	436	215:221
Mean	86	14	27	45	9.00±2.62	460	165:295

Disease data and tick challenge

Prevalence of trypanosome infection

Comparison of the parasitological prevalence of trypanosome infection in the Nkedi Zebu and Ankole cattle is presented in Table 2. Overall, 60 out of 1,841 (3.3%) animals were detected positive for trypanosome infection, of which 42 out of 1,178 (3.6%) were detected among the Nkedi Zebu cattle and 18 out of 663 (2.7%) among the Ankole cattle. The study area had a low trypanosome challenge, generally below a prevalence of 6% in either breed of cattle. Odds ratio for males/females was 2.1 implying that males had a two times higher risk to test positive than females. At this level of trypanosome challenge no statistically significant difference was observed between the prevalence of trypanosome infection in the Nkedi Zebu and Ankole cattle. Multivariable binary logistic regression indicated that risk to trypanosome infection was significantly ($P<0.05$) associated with the factors, individual farm, sampling site and gender (OR 1.02, 0.73 and 2.07, respectively). The overall model was significant ($P<0.05$) and factors, individual farm and gender had significant positive coefficients while sampling site had a significant negative coefficient. However, apart from gender (OR, 2.07; CI, 1.21–3.53), individual farm (OR, 1.02;CI, 1.00–1.03) and sampling site (OR, 0.73; CI, 0.56–0.94) did not have large effects despite being significant.

Prevalence of gastrointestinal nematode infection and mean faecal egg counts

Table 3 shows the comparison of arithmetic means of log-transformed faecal egg counts of the Nkedi Zebu and Ankole cattle. Cattle of either breed had low mean faecal egg counts independent of gender, age, season or sampling site: EPG of the Nkedi Zebu cattle ranged from 150 to 300 and that of the Ankole ranged from 110 to 230. The multivariable linear regression model indicated that age had a highly significant effect ($P<0.001$) on faecal egg count while gender had a significant effect ($P<0.05$). The regression equation was:

$$\mathrm{EPG} = 159 - 25.1\ \mathrm{Age} + 34.9\ \mathrm{Sex}$$

Table 4 shows the comparison of the prevalence of gastrointestinal nematode infections of the Nkedi Zebu and Ankole cattle. Cattle of either breed had high prevalence of gastrointestinal nematode infections. Ankole cattle generally had lower prevalence of gastrointestinal nematode infections (224/663=33.8%) than the Nkedi Zebu cattle (435/1,178= 36.9%) but there was no significant difference between the two breeds. However, during the first dry season, the Nkedi Zebu cattle had a significantly higher prevalence of gastrointestinal nematode infections than the Ankole cattle ($P<0.001$).

Multivariable binary logistic regression indicated that risk to gastrointestinal nematode infections was significantly

Table 2 Comparison of prevalence of trypanosome infections in Nkedi Zebu cattle to that of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	Trypanosome infections (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Prevalence (%)	*n*	Prevalence (%)	
Gender	Female	651	2.30±1.15	342	2.04±1.50	0.97
	Male	527	5.12±1.88	321	3.42±1.99	0.24
Age group (months)	0–6	54	0.00±0.0	71	1.40±2.76	
	7–12	125	4.80±3.76	69	5.88±3.83	0.41
	13–24	261	4.98±2.64	147	2.72±2.63	0.27
	Over 24	738	3.11±1.25	376	2.39±1.54	0.49
Season	Wet II	388	3.60±1.85	189	4.23±2.87	0.71
	Dry I	383	4.69±2.12	148	2.02±2.27	0.15
	Wet I	186	1.61±1.81	111	0.90±1.76	0.60
	Dry II	221	3.16±2.31	215	2.79±2.20	0.81
Site	Akumoi	295	5.42±2.58	133	6.01±4.05	0.79
	Aswii	66	1.51±2.20	178	1.12±1.55	
	Osamito	120	4.16±2.42	87	0.00±0.0	0.05
	Kamod	264	3.03±2.07	108	2.78±3.11	0.89
	Opungure	262	1.90±1.65	89	1.12±2.20	0.62
	Okokoma	171	4.09±2.97	68	5.88±5.63	0.55

Table 3 Comparison of the arithmetic mean of log-transformed faecal egg counts of Nkedi Zebu cattle to those of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	GIT nematode infection (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Mean EPG	*n*	Mean EPG	
Gender	Female	651	164.9±21.7	342	147.7±37.9	0.31
	Male	527	188.5±26.8	321	204.2±39.1	0.51
Age group (months)	0–6	54	224.1±86.1	71	171.1±55.7	0.31
	7–12	125	304.4±100.8	69	234.1±78.9	0.28
	13–24	261	163.4±27.6	147	143.2±33.0	0.37
	Over 24	738	154.3±16.6	376	177.4±34.5	0.24
Season	Wet II	388	170.1±25.7	189	192.3±57.0	0.48
	Dry I	383	201.4±33.4	148	198.0±49.8	0.91
	Wet I	186	158.6±48.7	111	113.1±31.2	0.12
	Dry II	221	154.1±33.3	215	176.0±34.1	0.36
Site	Akumoi	295	151.0±26.4	133	153.0±51.8	0.94
	Aswii	66	178.8±68.9	178	161.2±33.5	0.65
	Osamito	120	168.3±54.9	87	139.7±40.9	0.41
	Kamod	264	178.4±42.6	108	184.3±70.3	0.88
	Opungure	262	205.7±40.9	89	228.7±68.4	0.57
	Okokoma	171	170.5±33.7	68	214.7±100.5	0.41

($P<0.05$) associated with factors, age and sampling site (OR 0.86 and 1.08, respectively). The overall model was highly significant ($P<0.001$) and factors, age had significant negative coefficient while sampling site had a significant positive coefficient. However, neither age (OR, 0.86; CI, 0.78–0.95) nor sampling site (OR, 1.08; CI, 1.02–1.14) had large effects.

Tick counts

Table 5 shows the comparison of *R. appendiculatus* counts between the Nkedi Zebu and Ankole cattle. Both breeds had high mean counts of *R. appendiculatus* ticks (11–24 vs 12–24, respectively) with no significant difference between them. Multivariable linear regression revealed that factors,

Table 4 Comparison of prevalence of GIT nematode infection of Nkedi Zebu cattle to that of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	GIT nematode infection (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Prevalence (%)	*n*	Prevalence (%)	
Gender	Female	651	36.8±3.7	342	30.7±4.9	0.05
	Male	527	37.2±4.1	321	37.1±5.3	0.97
Age group (months)	0–6	54	44.4±13.4	71	32.4±11.0	0.16
	7–12	125	46.4±8.8	69	49.3±11.9	0.70
	13–24	261	37.2±5.9	147	33.3±7.9	0.43
	Over 24	738	34.7±3.4	376	31.4±4.7	0.94
Season	Wet II	388	36.6±4.8	189	32.1±6.7	0.98
	Dry I	383	42.0±5.0	148	38.5±7.9	0.00
	Wet I	186	30.1±6.6	111	21.6±7.7	0.11
	Dry II	221	34.4±6.3	215	38.1±6.5	0.41
Site	Akumoi	295	30.8±5.3	133	30.1±7.8	0.87
	Aswii	66	42.4±12.0	178	33.7±7.0	0.20
	Osamito	120	36.7±8.7	87	28.7±9.6	0.23
	Kamod	264	37.5±5.9	108	36.1±9.1	0.80
	Opungure	262	42.0±6.0	89	40.4±10.3	0.80
	Okokoma	171	36.8±7.3	68	35.3±11.4	0.82

Table 5 Comparison of mean counts of *Rhipecephalus appendiculatus* ticks of Nkedi Zebu cattle to those of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	*Rhipecephalus appendiculatus* counts (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Mean	*n*	Mean	
Gender	Female	651	20.2±0.75	342	19.8±1.19	0.57
	Male	527	22.2±0.97	321	21.4±1.13	0.29
Age group (months)	0–6	54	11.7±2.26	71	12.8±1.55	0.40
	7–12	125	15.7±1.47	69	15.8±1.84	0.94
	13–24	261	20.3±1.19	147	20.4±1.65	0.98
	Over 24	738	23.0±0.76	376	23.0±1.12	0.94
Season	Wet II	388	20.6±1.20	189	22.0±2.07	0.28
	Dry I	383	24.3±1.06	148	24.4±1.68	0.88
	Wet I	186	19.2±1.12	111	18.7±1.68	0.56
	Dry II	221	18.0±1.07	215	17.7±0.81	0.67
Site	Akumoi	295	24.7±1.52	133	22.8±2.13	0.15
	Aswii	66	16.4±3.11	178	18.4±1.65	0.23
	Osamito	120	22.5±1.75	87	23.1±2.35	0.71
	Kamod	264	22.1±1.12	108	21.3±1.82	0.45
	Opungure	262	19.4±0.96	89	20.2±1.86	0.42
	Okokoma	171	16.8±1.08	68	18.3±1.83	0.18

individual farm, herd size, sampling site, age, gender and season had significant influence ($P<0.05$) on *R. appendiculatus* counts. The regression equation was:

$$\textit{Rhipecephalus}\ \text{spp.} = 14.9 - 0.0354\ \text{farm} - 0.0448\ \text{herd size} - 0.641\ \text{sampling site} + 3.45\ \text{age} + 1.76\ \text{gender} - 1.54\ \text{season}$$

Comparison of mean counts of *R. (Boophilus) decoloratus* ticks between the Nkedi Zebu and Ankole cattle is shown in Table 6. Mean counts of *R. (Boophilus) decoloratus* ticks were moderate in number (3.0–9.0) but were lower than those of *R. appendiculatus* on either breed (11–24), and no significant differences were found between the two breeds. The multivariable linear regression model revealed that age, season, and gender had highly significant ($P<0.001$) influence on the *R. (Boophilus) decoloratus* counts.

The regression equation was: $R.(\textit{Boophilus})\ \textit{decoloratus} = -1.94 + 1.48\ \text{age} + 0.825\ \text{gender} + 1.29\ \text{season}$

Comparison of mean counts of *A. variegatum* ticks between the Nkedi Zebu and Ankole cattle is shown in Table 7. Mean tick counts of *A. variegatum* tick observed on the Nkedi Zebu (0.6–5.0) and Ankole cattle (1.0–4.4) were lower than those of *R. appendiculatus* (11–24) and *R. (Boophilus) decoloratus* (3.0–9.0) and no significant difference was observed between mean counts of *A. variegatum* of Nkedi Zebu and Ankole cattle. The multivariable linear regression model revealed that age, season and gender had highly significant influence ($P<0.001$) on *A. variegatum* counts.

The regression equation was: $\textit{Amblyomma}\ \text{spp.} = -0.019 + 1.01\ \text{age} + 1.03\ \text{gender} - 0.673\ \text{season}$

Response to disease challenge

Mean PCV values and proportion of cattle anaemic

A comparison of mean PCV values among the Nkedi Zebu and Ankole cattle is shown in Table 8. No significant difference was observed between the Nkedi Zebu and Ankole cattle in terms of mean PCV. The multivariable linear regression model revealed that factors, individual farm, herd size, sampling site, gender and season had highly significant ($P<0.001$) effect on PCV values. The regression equation was:

$$\text{PCV} = 29.3 - 0.0417\ \text{farm} - 0.0437\ \text{herd size} + 0.412\ \text{sampling site} - 0.635\ \text{gender} + 0.473\ \text{season}$$

Table 9 shows the comparison of percentage of animals anaemic between the Nkedi Zebu and Ankole cattle. The Nkedi Zebu cattle had significantly lower

Table 6 Comparison of mean counts of *Rhipecephalus (Boophilus) decoloratus* ticks of Nkedi Zebu cattle to those of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	*Rhipecephalus (Boophilus) decoloratus* counts (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Mean	*n*	Mean	
Gender	Female	651	7.0±0.42	342	6.8±0.64	0.66
	Male	527	7.6±0.51	321	7.4±0.60	0.53
Age group (months)	0–6	54	3.5±1.15	71	3.3±0.92	0.73
	7–12	125	5.0±0.84	69	5.6±0.95	0.30
	13–24	261	7.2±0.65	147	7.0±0.89	0.77
	Over 24	738	8.0±0.42	376	8.1±0.62	0.73
Season	Wet II	388	3.6±0.50	189	3.8±0.67	0.77
	Dry I	383	10.3±0.59	148	9.6±1.27	0.35
	Wet I	186	7.3±0.66	111	7.8±0.99	0.40
	Dry II	221	8.5±0.50	215	7.9±0.46	0.09
Site	Akumoi	295	6.3±0.74	133	6.0±1.08	0.71
	Aswii	66	4.0±1.45	178	5.8±0.79	0.02
	Osamito	120	8.6±1.01	87	9.1±1.58	0.55
	Kamod	264	7.4±0.63	108	8.2±0.81	0.14
	Opungure	262	8.7±0.66	89	8.1±1.14	0.34
	Okokoma	171	7.0±0.67	68	7.1±1.01	0.89

percentage of animals anaemic than Ankole cattle during the first wet season ($P<0.05$). Multivariable binary logistic regression indicated that risk to anaemia was significantly ($P<0.001$) associated with herd size and season (OR, 1.01 and 0.77, respectively). The overall model was highly significant ($P<0.001$) and the factor herd size had a significant positive coefficient while season a significant negative coefficient. However, herd

Table 7 Comparison of mean counts of *Amblyomma variegatum* ticks of Nkedi Zebu cattle to those of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	*Amblyomma variegatum* counts (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Mean	*n*	Mean	
Gender	Female	651	2.8±0.34	342	2.8±0.44	0.65
	Male	527	4.1±0.43	321	3.6±0.53	0.22
Age group (months)	0–6	54	0.6±0.42	71	1.2±0.78	0.22
	7–12	125	1.8±0.56	69	1.6±0.82	0.66
	13–24	261	3.1±0.56	147	3.0±0.66	0.83
	Over 24	738	3.9±0.36	376	4.0±0.49	0.73
Season	Wet II	388	4.0±0.53	189	4.3±0.83	0.94
	Dry I	383	3.6±0.49	148	4.0±0.74	0.74
	Wet I	186	2.9±0.60	111	3.2±0.76	0.60
	Dry II	221	2.2±0.43	215	1.7±0.35	0.13
Site	Akumoi	295	3.1±0.54	133	3.1±0.72	0.96
	Aswii	66	3.0±1.06	178	2.6±0.64	0.46
	Osamito	120	5.0±1.06	87	4.4±1.15	0.53
	Kamod	264	3.9±0.63	108	3.6±0.91	0.52
	Opungure	262	3.8±0.53	89	4.0±0.92	0.67
	Okokoma	171	1.4±0.36	68	2.0±0.72	0.09

Table 8 Comparison of mean PCV values of Nkedi Zebu cattle to those of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	PCV values (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Mean	*n*	Mean	
Gender	Female	638	28.7±0.40	338	28.0±0.51	0.14
	Male	520	27.7±0.40	316	28.2±0.56	0.00
Age group (months)	0–6	50	27.8±1.50	71	27.6±1.12	0.52
	7–12	123	28.3±0.83	68	27.8±1.10	0.56
	13–24	257	28.4±0.63	147	28.8±0.83	0.31
	Over 24	728	28.2±0.36	368	28.0±0.50	0.60
Season	Wet II	388	27.6±0.47	189	27.4±0.68	0.83
	Dry I	363	26.3±0.36	139	26.5±0.71	0.49
	Wet I	186	31.2±0.65	111	30.4±1.00	0.19
	Dry II	221	30.0±0.69	215	28.6±0.63	0.00
Site	Akumoi	295	29.0±0.52	133	29.2±0.77	0.55
	Aswii	66	26.4±1.10	178	26.9±0.67	0.83
	Osamito	120	28.5±0.90	87	28.8±1.07	0.73
	Kamod	264	27.7±0.63	108	26.9±0.91	0.27
	Opungure	262	28.2±0.60	80	28.5±1.14	0.51
	Okokoma	171	28.4±0.83	68	29.6±1.24	0.05

Table 9 Comparison of percentage of Nkedi Zebu cattle anaemic to that of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	Percentage anaemic[a] (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Anaemic (%)	*n*	Anaemic (%)	
Gender	Female	638	22.1±3.2	338	20.7±4.3	0.60
	Male	520	25.0±3.7	316	23.7±4.7	0.01
Age group (months)	0–6	50	26.0±12.3	71	22.5±9.8	0.66
	7–12	123	22.8±7.3	68	19.1±9.4	0.55
	13–24	257	23.0±5.3	147	19.7±6.5	0.44
	Over 24	728	23.5±3.1	368	23.6±4.3	0.29
Season	Wet II	388	24.0±4.3	189	24.3±6.1	0.95
	Dry I	363	36.6±5.0	139	31.7±7.8	0.26
	Wet I	186	7.0±3.7	111	15.3±6.7	0.02
	Dry II	221	14.5±4.6	215	17.7±5.1	0.36
Site	Akumoi	295	16.6±4.3	133	14.3±6.0	0.54
	Aswii	66	33.3±11.5	178	28.7±6.7	0.81
	Osamito	120	20.0±7.2	87	19.5±8.4	0.93
	Kamod	264	30.3±5.6	108	32.4±8.9	0.81
	Opungure	262	20.2±5.1	80	15.0±7.9	0.29
	Okokoma	171	27.5±6.7	68	16.2±8.8	0.06

[a] Anaemic cattle had PCV <25

size (OR, 1.01; CI, 1.01–1.02) and season (OR, 0.77; CI, 0.69–0.85) did not have large effects.

Mean OD values of antibodies against T. parva, B. bigemina and A. marginale infections

Comparison of mean OD values of antibodies against *T. parva* infections of the Nkedi Zebu to those of the Ankole cattle is shown in Table 10. Generally, the Nkedi Zebu cattle had higher mean OD values than the Ankole cattle but not significantly different. However, the multivariable linear regression model revealed that the factor season had a highly significant ($P<0.001$) effect on titre of antibodies against *T. parva* infections in cattle. The regression equation was:

$$\text{OD } T.parva = 0.486 + 0.106\ \text{breed} + 0.034\ \text{sampling site} + 0.305\ \text{season}$$

Even though *R .appendiculatus* tick burden was similar between matching age groups of the Nkedi Zebu and Ankole cattle, a clear difference in antibody profile was observed between the Nkedi Zebu and Ankole cattle (Fig. 2). The Nkedi Zebu cattle started with a high titre of antibody at 0–6 months when maternal antibodies were present, then the antibody titre decreased at 7–12 months, but later increased gradually at 13–24 months and continued further at >24 months On the contrary, the Ankole cattle started with low antibody titre at 0–6 months and steadily increased as the animals grew older.

A comparison of the mean OD values of antibodies against *B. bigemina* infection of the Nkedi Zebu cattle to those of Ankole cattle is shown in Table 11. The Nkedi Zebu females had a significantly higher ($P<0.001$) titre of antibodies against *B. bigemina* infection (1.790±0.143) than Ankole females (1.426±0.182). In addition, the Nkedi Zebu yearlings had a significantly higher titre of antibodies against *B. bigemina* infection (1.762±0.222) than the Ankole yearlings (1.373±0.241). Similarly, adult Nkedi Zebu cattle (over 24 m) had a significantly higher ($P<0.05$) antibody titre against *B. bigemina* infection (1.807±0.133) than adult Ankole (1.564±0.159). Generally, both breeds had high titre of antibodies against *B. bigemina* infection and had similar antibody profile with antibodies titres increased with age.

During the wet season, the Nkedi Zebu cattle had a significantly higher ($P<0.05$) titre of antibodies against *B. bigemina* infection (1.075±0.133) than the Ankole cattle (0.863±0.098). Variation in antibody production against *B. bigemina* infection between the Nkedi Zebu and Ankole cattle was also witnessed on considering sampling sites. For instance, the Nkedi Zebu cattle in Kamod (1.754±0.242) and Okokoma (2.405±0.134) sampling sites had significantly higher antibody titres ($P<0.05$) than the Ankole cattle (1.323±0.308, 1.519±0.305, respectively). The multivariable linear regression model revealed that season significantly ($P<0.001$) influenced the titre of antibodies

Table 10 Comparison of mean OD values of antibody against *Theileria parva* infection in Nkedi Zebu cattle to those of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	Titre of antibody against *T. parva* infection (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Mean OD values	*n*	Mean OD values	
Gender	Female	96	1.297±0.136	75	1.175±0.148	0.23
	Male	90	1.302±0.128	91	1.134±0.119	0.06
Age group (months)	0–6	10	1.455±0.492	15	0.993±0.369	0.15
	7–12	22	1.224±0.299	16	1.156±0.308	0.75
	13–24	46	1.274±0.190	40	1.156±0.181	0.38
	Over 24	108	1.311±0.121	95	1.176±0.123	0.12
Season	Wet II	77	1.093±0.156	91	1.030±0.136	0.54
	Dry I	109	1.445±0.109	75	1.302±0.116	0.07
Site	Akumoi	38	1.142±0.179	34	1.170±0.189	0.83
	Aswii	27	1.351±0.282	24	0.835±0.261	0.01
	Osamito	32	1.202±0.221	35	1.226±0.189	0.87
	Kamod	45	1.307±0.207	22	1.335±0.249	0.86
	Opungure	25	1.441±0.241	26	1.188±0.179	0.10
	Okokoma	19	1.498±0.252	25	1.134±0.306	0.07

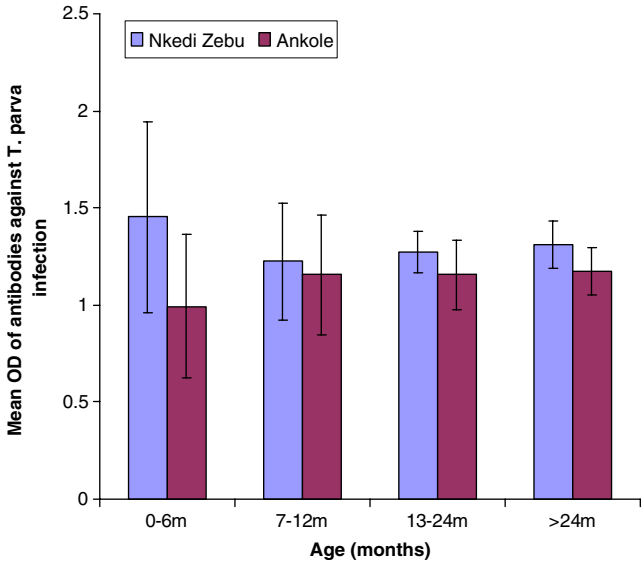

Fig. 2 Comparison of profiles of antibodies against *Theileria parva* infection in Nkedi Zebu cattle (n=186) and Ankole cattle (n=166) under natural tick challenge in Soroti district, Uganda, 2007

against *B. bigemina* infection in cattle. The linear regression equation was:

$$\text{OD } B.\ bigemina = -0.397 + 0.114\ \text{breed} + 1.19\ \text{season}$$

We also compared mean OD values of antibodies against *A. marginale* infection of the Nkedi Zebu to those of the Ankole cattle and the data are shown in Table 12. Generally, both breeds had low titre of antibodies against *A. marginale* infection. In addition, both breeds exhibited similar antibody profiles and antibody titres increased with age. It was however observed that Nkedi Zebu yearlings (0.673±0.124) had significantly higher (P<0.001) titres of antibodies against *A. marginale* infection than Ankole yearlings (0.448±0.103). During the wet season, the Nkedi Zebu cattle (0.578±0.082) had significantly higher (P< 0.001) titre of antibody against *A. marginale* infection than the Ankole cattle (0.442±0.050). Multivariable linear regression revealed that season had a significant (P<0.05) influence on the titre of antibodies against *A. marginale* infection in cattle. The linear regression equation was:

$$\text{OD } A.marginale = 0.417 + 0.0871\ \text{season}$$

Production performance

Mean daily milk production, draught power output and liveweight of the Nkedi Zebu and Ankole cattle are summarised in Table 13. The Ankole cows produced significantly more (P<0.001) milk per day (2.68 L) than the Nkedi Zebu cows (1.98 L). In addition, the Ankole oxen produced significantly higher (P<0.05) draught power output (2.57 days/acre) than the Nkedi Zebu oxen (2.93 days/acre). However, there was no significant difference between mean liveweight of the Nkedi Zebu (50.6 kg) and Ankole (57.4 kg) female calves aged 0–6 months (P=0.25) or between mean liveweight of the Nkedi Zebu (54.5 kg) and Ankole (55.3 kg) males aged 0–6 months (P=0.87). Likewise, there was no

Table 11 Comparison of mean OD values of antibody against *B.bigemina* infection in Nkedi Zebu cattle to those of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	Titre of antibody against *B. bigemina* infection (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Mean OD values	*n*	Mean OD values	
Gender	Female	96	1.790±0.143	75	1.426±0.182	0.00
	Male	90	1.644±0.164	91	1.463±0.158	0.11
Age group (months)	0–6	10	1.182±0.529	15	1.078±0.344	0.75
	7–12	22	1.446±0.344	16	1.277±0.346	0.50
	13–24	46	1.762±0.222	40	1.373±0.241	0.02
	Over 24	108	1.807±0.133	95	1.564±0.159	0.02
Season	Wet II	77	1.075±0.133	91	0.863±0.098	0.01
	Dry I	109	2.175±0.088	75	2.154±0.090	0.74
Site	Akumoi	38	1.833±0.215	34	1.596±0.274	0.18
	Aswii	27	1.601±0.273	24	1.343±0.338	0.25
	Osamito	32	1.302±0.209	35	1.393±0.219	0.55
	Kamod	45	1.754±0.242	22	1.323±0.308	0.03
	Opungure	25	1.628±0.323	26	1.452±0.344	0.46
	Okokoma	19	2.405±0.134	25	1.519±0.305	0.00

Table 12 Comparison of mean OD values of antibody against *A. marginale* infection in Nkedi Zebu cattle to those of Ankole cattle in Soroti district, Uganda, according to gender, age group, season and study site, 2007

Factor	Level	Titre of antibody against *A. marginale* infection (±95% CI)				*P* value
		Nkedi Zebu		Ankole		
		n	Mean OD values	*n*	Mean OD values	
Gender	Female	96	0.549±0.076	75	0.502±0.083	0.41
	Male	90	0.615±0.092	91	0.524±0.083	0.15
Age group (months)	0–6	10	0.555±0.215	15	0.510±0.210	0.77
	7–12	22	0.599±0.221	16	0.621±0.223	0.89
	13–24	46	0.673±0.124	40	0.448±0.103	0.00
	Over 24	108	0.541±0.073	95	0.525±0.080	0.78
Season	Wet II	77	0.578±0.082	91	0.442±0.050	0.00
	Dry I	109	0.583±0.100	75	0.603±0.114	0.78
Site	Akumoi	38	0.637±0.112	34	0.602±0.148	0.71
	Aswii	27	0.580±0.127	24	0.443±0.050	0.09
	Osamito	32	0.379±0.077	35	0.394±0.135	0.85
	Kamod	45	0.701±0.146	22	0.684±0.179	0.89
	Opungure	25	0.654±0.212	26	0.546±0.133	0.40
	Okokoma	19	0.432±0.149	25	0.451±0.148	0.86

significant difference between mean liveweight of the Nkedi Zebu (95.9 kg) and Ankole (101.8 kg) females aged 7–12 months (P=0.50) or between mean liveweight of Nkedi Zebu (96.4 kg) and Ankole (94.8 kg) males aged 7–12 months (P=0.86). Similar mean liveweights among the two breeds suggested that both the Nkedi Zebu and Ankole cattle under this disease challenge exhibited similar growth rates.

Discussion

Of the herds screened, few had either the Nkedi Zebu or Ankole cattle alone and the majority had mixed breeds of cattle. The Ankole cattle constituted between 28% and 37% of the cattle sampled during the study visits, having been brought into Soroti district between 1998 and 2000 during the restocking exercise (Magona et al. 2004). Originally, the Ankole cattle were traditionally kept by nomadic pastoralists in western parts of Uganda (Wurzinger et al. 2006), while Nkedi Zebu cattle were kept in eastern Uganda by smallholder farmers (Magona et al. 2004). The two breeds constitute almost all (>95%) cattle in Uganda (Magona et al. 2004). Studies based on frequency of either taurine or indicine γ specific allele revealed that the two cattle types are genetically different with the Nkedi Zebu having predominantly indicine allele and the Ankole having predominantly taurine allele (Hanotte et al. 2000).

No significant difference was observed between the prevalence of trypanosome infection in the Ankole and

Table 13 Comparison of daily milk production of cows, draught power output of oxen and weight of calves of Nkedi Zebu cattle to those of Ankole cattle in Soroti district, Uganda, 2007

	Nkedi Zebu		Ankole		*P* value
	n	Values (±95% CI)	*n*	Values (±95% CI)	
Mean daily milk yield (litres)	84	1.98±0.14	54	2.68±0.22	0.00
Mean number of days oxen plough an acre of land (days)[a]	82	2.93±0.20	44	2.57±0.21	0.01
Mean weight of female calves aged 0–6 months (kg)	12	50.6±7.1	24	57.4±9.0	0.25
Mean weight of female calves aged 7–12 months (kg)	32	95.9±7.8	10	101.8±14.9	0.50
Mean weight of male calves aged 0–6 months (kg)	16	54.5±6.6	19	55.3±6.8	0.87
Mean weight of male calves aged 7–12 months (kg)	22	96.4±9.5	10	94.8±14.6	0.86

[a] Ankole oxen were bigger in size and stronger hence required significantly fewer days to plough an acre of land

Nkedi Zebu cattle, probably because of the low trypanosome challenge. Previous studies suggested that the Nkedi Zebu have a lower prevalence of trypanosomosis than the Ankole cattle under high trypanosome challenge but have similar prevalence of trypanosomosis under low or medium trypanosome challenge (Magona et al. 2004, 2005).

Generally, the Nkedi Zebu and Ankole cattle had low faecal egg counts and high prevalence of gastrointestinal nematode infections. Faecal egg counts were significantly influenced by age and gender rather than breed. Despite our findings, low susceptibility to helminthosis by the Zebu cattle in East Africa has been reported previously (Bitakaramire 1973; Magona and Mayende 2002). In addition, studies conducted in Australia demonstrated that *B. indicus* cross-bred yearlings were more resistant to parasites than *B. taurus* breeds (O'Kelly 1980).

The Nkedi Zebu and Ankole cattle equally had high mean counts of *R. appendiculatus* ticks with no significant difference between them. Correspondingly, both host factors, age and gender, and external factors, individual farm, herd size, sampling site and season influenced *R. appendiculatus* tick burden on the two breeds alike, suggesting both breeds could have similar level of resistance to *R. appendiculatus*. High *R. appendiculatus* counts were observed on individual animals among both breeds implying that a few individual animals among both breeds had low resistance to this tick species and were experiencing a resistance breakdown to *R. appendiculatus*. Such a phenomenon has been reported (Dipeolu et al. 1992) and is responsible for why such indigenous African breeds still carry large numbers of ticks even when they are exposed to ticks for a long time (Dossa et al. 1996)

Mean counts of *R. (Boophilus) decoloratus* ticks were moderate in number on both the Nkedi Zebu and Ankole cattle and were lower than those of *R. appendiculatus* on either breed. Both host and external factors influenced *R. (Boophilus) decoloratus* burden on both breeds, suggesting similar level of resistance to *R. (Boophilus) decoloratus* ticks. Regarding *A. variegatum* ticks, mean counts on both the Nkedi Zebu and Ankole cattle were low. Age, season and gender had highly significant influence on *A. variegatum* counts on both the Nkedi Zebu and Ankole cattle, suggesting that both breeds had similar level of resistance to *A. variegatum*. Moderate to low counts of *R. (Boophilus) decoloratus* and *A. variegatum*, respectively, observed on both breeds suggested that the Nkedi Zebu and Ankole cattle equally had high level of resistance to *R. (Boophilus) decoloratus* and *A. variegatum* tick species. Highly resistant cattle are reported to show little or no seasonal variation in tick numbers (Latif et al. 1991b).

The Nkedi Zebu cattle had a significantly higher percentage of cattle anaemic than the Ankole only during wet season. It was further observed that mean PCV values and the percentage of cattle anaemic were influenced by host factors such as gender and external factors such as individual farm, herd size, sampling site and season. This might suggest that management factors rather than breed difference were responsible to variations in PCV. Previous reports have however suggested that differences in PCV is considered to represent differences in varying degrees of anaemia among different indigenous breeds, reflecting existing variations in innate resistance to parasitic diseases (Magona and Mayende 2002).

The Nkedi Zebu cattle had higher mean OD values of antibodies against *T. parva* infections than the Ankole cattle, suggesting that the Nkedi Zebu cattle were capable of mounting a higher immunological response against *T. parva* infection than the Ankole cattle. Probably the immunological response against *T. parva* infection was not so distinct among the two breeds since significant differences were only observed at one study site. Nevertheless, the Nkedi Zebu cattle had a distinct antibody profile compared with the Ankole cattle. Little is known about how the Nkedi Zebu respond to *T. parva* infection in terms of parasite control mechanism, however, Ankole cattle are known to have genetic ability to limit the explosive multiplication of macroschizonts (Paling et al. 1991).

The Nkedi Zebu cattle of all categories had significantly higher mean OD values of antibody against *B. bigemina* infection than the Ankole cattle, suggesting that the Nkedi Zebu were capable of mounting a significantly stronger immunologically response against *B. bigemina* infection than the Ankole cattle. Similarly, the Nkedi Zebu cattle appeared to mount a stronger immunological response against *A. marginale* infection than the Ankole cattle. Both breeds had similar antibody profiles for *B.bigemina* and *A. marginale* infections and antibody titres increased with age.

Ankole cows had a significantly higher milk yield than the Nkedi Zebu cows, and Ankole oxen produced significantly higher draught power output than the Nkedi Zebu oxen. Young animals aged 0–6 and 7–12 months of both breeds, had similar liveweight implying that calves exhibited similar growth rates independent of breed. It appears that the Ankole cattle have been selected for their productive traits such as milk yield and body size, traits highly valued by traditional livestock keeper in this region (Wurzinger et al. 2006). On the other hand, the Nkedi Zebu appears to have been selected for their adaptive traits such as disease resistance. Zebus are also considered to be drought resistant and are unselected feeders and thus deal better with harsh environment and poor pastures (Wurzinger et al. 2006).

Our findings suggested that the Nkedi Zebu and Ankole cattle exhibited similar level of susceptibility to

trypanosome infections and gastrointestinal nematode under low to medium challenge. It is likely that the Nkedi Zebu and Ankole cattle had similar level of resistance to *R. appendiculatus, R. (Boophilus) decoloratus* and *A. variegatum* tick species under natural challenge in Uganda, but the Nkedi Zebu cattle appeared to be more capable of mounting a higher immunological response against *T. parva, B. bigemina* and *A. marginale* infections than Ankole cattle. On the contrary, the Ankole cows produced significantly higher amount of milk per day than the Nkedi Zebu cows, and Ankole oxen produced significantly higher draught power output than the Nkedi Zebu oxen, but both breeds appeared to exhibit similar growth rates under similar disease challenge. Further in-depth studies are required to confirm these findings; however, the Nkedi Zebu cattle seem to possess a higher degree of disease resistance against endemic parasitic diseases, while the Ankole cattle seem to possess a moderate degree of disease resistance coupled with a moderate production potential.

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Conflicts of interest None

References

Ajayi, S. A., Fabiyi, J. P. and Umo, I., 1982. Clinical bovine anaplasmosis and babesiosis in Friesian cattle in an outbreak in Nigeria and its control, World Animal Review, 43, 41.

Bakheit, M. A. and Latif, A.A., 2005. The innate resistance of Kenana cattle to tropical theileriosis (*Theileria annulata* infection) in the Sudan, Annals New York Academy of Sciences, 969, 159–163.

Bitakaramire, P. K., 1973. The incidence of fascioliasis in different breeds of cattle in Kenya, Bulletin of Animal Health and Production in Africa, 21, 145–152.

Chandler, R.L., 1958. Studies on the tolerance of N'Dama cattle to trypanosomiasis, Journal of Comparative Pathology, 68, 253.

Dipeolu, O.O., Mongi, A.O., Essuman, S., Amoo, A.O. and Ndungu, J.N., 1992. Studies on naturally acquired immunity to African ticks. II. Observations on cattle exposed to *Rhipicephalus appendiculatus* under varying periods of repeated infestation, Veterinary Parasitology, 41, 293–320.

Dossa, S.C., Kaaya, G.P., Essuman, S., Odulaja, A. and Assoku, R.G. K., 1996. Acquisition of resistance to the tick *Amblyomma variegatum* in Boran cattle, *Bos indicus* and the effects of *Trypanosoma congolense* and *Babesia bigemina* on host resistance, Veterinary Parasitology, 62, 317–330.

FAO, 2006. Farm animal biodiversity. Avaialable at: http://www.fao.org/Ag/

Feleke, A., Petros, B., Mulatu, W., Lemecha, H., Wossene, A. and Rege, J.O., 2007. Resistance of Abigar, Guraghe, Horro and Sheko breeds of cattle to tick infestation in Ghibe-Tolley Valley, Bulletin of Animal Health and Production in Africa, 55, 163–174.

Gibson, J.P., Bishop, S.C., 2005. Use of molecular markers to enhance resistance of livestock to disease: a global approach, Revue scientifique et technique (International Office of Epizootics), 24 (1), 343–353

Hanotte, O., Tawah, C.L., Bradley, D.G., Okomo, M., Verjee, Y., Ochieng, J. and Rege, J.E., 2000. Geographic distribution and frequency of a taurine *Bos taurus* and an indicine *Bos indicus* γ specific allele amongst sub- Saharan African cattle breeds, Molecular Ecology, 9, 387–396.

Hansen, J. and Perry, B., 1994. The epidemiology, diagnosis and control of helminth parasites of ruminants. International Laboratory for Research on Animal diseases (ILRAD), Nairobi, Kenya.

Ismael, A.A., Njogu, A.R., Gettinby, G. and Murray M., 1985. Susceptibility of Orma and Galana Boran cattle to infection with bloodstream forms of Trypanosoma congolense and T. vivax. In: International Scientific Conference for Trypanosomiasis Research and Control, 18th Meeting Harare, Zimbabwe, 1985, OAU/STRC, No. 113, 176.

Jacobsen, P., 1983. East Coast Fever as a cause of calf mortality in Zanzibar, Tropical Animal Health and Production, 15, 43–46.

Kaufmann, J. and Pfister, K., 1990. The seasonal epidemiology of gastrointestinal nematodes in N'Dama cattle in The Gambia, Veterinary Parasitology, 37, 45–54.

Kaufmann, J., Dwinger, R. H., Hallebeek, A., van Dijk, B. and Pfister, K., 1992. The interaction of *Trypanosoma congolense* and *Haemonchus contortus* infections in trypanotolerant N'Dama cattle, Veterinary Parasitology, 43, 157–170.

Latif, A.A., Nokoe, S., Punyua, D.K. and Capstick P.B., 1991a. Tick infestations on Zebu cattle in western Kenya: quantitative assessment of host resistance, Journal of Medical Entomology, 28 (1), 122–126.

Latif, A.A., Punyua, D.K., Nokoe, S. and Capstick P.B., 1991b. Tick infestations on Zebu cattle in western Kenya: individual host variation, Journal of Medical Entomology, 28 (1), 114–121.

Latif, A. A., Rowlands, G. J., Punyua, D. K., Hassan, S. M. and Capstick, P. B., 1995. An epidemiological study of tick-borne diseases and their effects on productivity of Zebu cattle under traditional management on Rusinga Island, Western Kenya, Preventive Veterinary Medicine, 22, 169–181.

Lemecha, H., Mulatu, W., Hussein, I., Rege, E., Tekle, T., Abdicho, S. and Ayalew, W., 2006. Response of four indigenous cattle breeds to natural tsetse and trypanosomosis challenge in the Ghibe Valley of Ethiopia, Veterinary Parasitology, 141, 165–176.

Magona, J.W. and Mayende, J.S.P., 2002. Occurrence of concurrent trypanosomosis, theileriosis, anaplasmosis and helminthosis in Friesian, Zebu and Sahiwal cattle in Uganda, Onderstepoort Journal of Veterinary Research, 69, 133–140.

Magona, J.W., Walubengo, J. and Odimim, J.J., 2004. Differences in susceptibility to trypanosome infection between Nkedi Zebu and Ankole cattle under field conditions in Uganda, Annals of Tropical Medicine and Parasitology, 98(8), 785–792.

Magona, J.W., Walubengo, J. and Odimim, J.J., 2005. Comparison of trypanosome infection between Nkedi Zebu and Ankole cattle under high tsetse challenge in Uganda. In: International Scientific Conference for Trypanosomiasis Research and Control, 28th Meeting Addis Ababa, Ethiopia, 2005. Available at: http://www.au-ibar.org/isctrc/28Meeting/

Magona, J.W., Walubengo, J., Olaho-Mukani, W., Jonsson, N.N., Welburn, S.C. and Eisler, M.C., 2008. Clinical features associated with seroconversion to *Anaplasma marginale*, *Babesia*

bigemina and *Theileria parva* infections in African cattle under natural tick challenge, Veterinary Parasitology, 155, 273–280.

Mattioli, R.C., Jaitner, J., Clifford, D.J., Pandey, V.S. and Verhulst, A., 1998. Trypanosome infections and tick infestations: susceptibility in N'Dama, Gobra Zebu and Gobra X N'Dama crossbred cattle exposed to natural challenge and maintained under high and low surveillance of trypanosome infections, Acta Tropica, 71, 57–71.

Murray, M., Murray, P. K. and McIntyre, W. I. M., 1977. An improved parasitological technique for the diagnosis of African trypanosomiasis, Transactions of the Royal Society of Tropical Medicine and Hygiene, 71, 325–326.

Murray, M., Clifford, D.J., Gettinby, G., Snow W.F. and McIntyre, W. I.M., 1981. A study of the susceptibility to African trypanosomiasis of N'Dama and Zebu cattle in an area of Glossina morsitans submorsitans challenge, Veterinary Record, 109, 503.

Mwangi, E.K., Stevenson, P., Gettinby, G., Reid, S.W.J. and Murray, M., 1998a. Susceptibility to trypanosomosis of three Bos indicus cattle breeds in areas of differing tsetse fly challenge, Veterinary Parasitology, 79, 1–17.

Mwangi, E.K., Stevenson, P., Ndungu, J.M., Stear, M.J., Reid, S., Gettinby, G. and Murray, M., 1998b. Studies on host resistance to tick infestation among trypanotolerant Bos indicus cattle breeds in East Africa, Annals of New York Academy of Science, 849, 195–200.

Njogu, A. R., Dolan, R.B., Wilson, A.J. and Sayer, P.D., 1985. Trypanotolerance in East African Orma Boran cattle, Veterinary Record, 117, 632.

O'Kelly, J.C., 1980. Parasitism and blood composition in genetically different types of cattle grazing in a tropical environment, Veterinary Parasitology, 6, 381–390.

Okello-Onen, J., Tukahirwa, E. M., Perry, B. D., Rowlands, G. J., Nagda, S. M., Musisi, G., Bode, E., Heinonen, R., Mwayi, W. and Opuda-Asibo, J., 1999. Population dynamics of ticks on indigenous cattle in a pastoral dry to semi-arid rangeland zone of Uganda, Experimental and Applied Acarology, 23, 79–88.

Paling, R. W., Mpangala, C., Luttikhuizen, B. Sibomana, G., 1991. Exposure of Ankole and crossbred cattle to theileriosis in Rwanda, Tropical Animal Health and Production, 23, 203–214.

Rege, J.E.O. 1999. The state of African cattle genetic resources I. Classification framework and identification of threatened and extinct breeds. Animal Genetic Resources Information, 25, 1–25.

Rice, A. 2008. A dying breed. http://nytimes.com/2008.

Stewart, J.L., 1951. The West African Shorthorn cattle. Their value to Africa as trypanosomiasis resistant animals, Veterinary Record, 63, 454.

Thrusfield, M., 1995. Veterinary Epidemiology, Blackwell, Oxford.

Wambura, P.N., Gwakisa, P.S., Silayo, R.S. and Rugaimukamu, E.A., 1998. Breed-associated resistance to tick infestation in Bos indicus and their crosses with *Bos taurus*, Veterinary Parasitology, 77, 63–77.

Waruiru, R. M., Nansen, P., Kyvsgaard, N. C., Thamsborg, S. M., Munyua, W. K., Gathuma, J. M. and Bøgh, H. O., 1998. An abattoir survey of gastrointestinal nematode infections in cattle in the Central Highlands of Kenya, Veterinary Research Communications, 22, 325–334.

Woo, P. K. T., 1969. The haematocrit centrifugation technique for the detection of trypanosomiasis in blood, Canadian Journal Zoology, 47, 921–923.

Wurzinger, M., Ndumu, D., Baumung, R., Drucker, A., Okeyo, A.M., Semambo, D.K., Byamungu, N. and Sölkner, J., 2006. Comparison of production systems and selection criteria of Ankole cattle by breeders in Burundi, Rwanda, Tanzania and Uganda, Tropical Animal Health and Production, 38, 571–581.