Variations in susceptibility to the effects of trypanosomiasis in East African zebu cattle

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INTRODUCTION

Bovine trypanosomiasis is prevalent in 66,000 km² of southwest Ethiopia infested with tsetse flies (Ford et al., 1976; Krug, 1971). Since 1986, East African zebu cattle raised under trypanosomiasis risk in the Ghibe valley of southwest Ethiopia have been studied to investigate the effects of trypanosomiasis on health and productivity. As the project progressed it became apparent that many animals were repeatedly being detected parasitaemic despite treatment with diminazene aceturate at a dose of 3.5 mg/kg bodyweight (Rowlands et al., 1993). A model to distinguish between new and recurrent infections was developed (Rowlands et al., 1991) in order to determine if the high infection rate following treatment of Trypanosoma congolense infections, the predominant species, was due solely to the high tsetse challenge or instead to relapses of infections following treatment. Rowlands et al. (1993) showed that changes in T. congolense prevalence matched corresponding changes in tsetse challenge. However, the number of detected parasitaemias attributable to new infections accounted for only about two thirds of all parasitaemias, implying that a proportion of the detected parasitaemias was due to recurrent infections.

These results pointed to the existence of drug resistant trypanosomes and this was confirmed by Codjia et al. (1993). Twelve stabilates obtained from cattle at Ghibe were inoculated into individual Boran calves and characterized for their sensitivity to diminazene aceturate, isometamidium chloride and homidium chloride. All 12 stabilates produced infections resistant to treatment with diminazene aceturate, while 11 produced infections resistant to isometamidium chloride and homidium chloride. With this evidence of very high levels of drug resistance under laboratory conditions it is perhaps surprising that a higher prevalence of parasitaemia was not being detected in the field. The prevalence of T. congolense at the time that isolates were collected was 37%. It would appear, therefore, that, whilst treatment may not have been eliminating infections, it may have
helped to limit the trypanosome growth and allowed the cattle to maintain reasonable health and condition.

This paper examines the associations between parasitaemia and production and investigates whether, within this environment, some animals were able to exhibit reduced susceptibility than others to the effects of trypanosomiasis.

MATERIALS AND METHODS

Approximately 840 ear-tagged East African zebu cattle from nine village herds in the Ghibe valley, southwest Ethiopia, have been weighed and sampled monthly since March 1986. These cattle were of varying ages, including calves and mature cattle. Blood samples were collected for the estimation of packed blood cell volume (PCV) and for the detection of trypanosomes using the darkground/phase contrast buffy coat technique (Murray et al., 1977). Animals with a PCV below 26% and detected parasitaemic, or animals showing clinical signs of trypanosomiasis, were treated with diminazene aceturate at 3.5 mg/kg bodyweight. Eighty-seven per cent of all animals found parasitaemic during 1986 to 1991 had a PCV < 26% and were treated. Ten per cent of treatments were administered to animals which showed clinical signs but which were not detected parasitaemic. Adult animals were treated on average three times a year.

Further details of the management of these cattle are given by Leak et al. (1993) and Rowlands et al. (1993).

Statistical Analysis

Effect of parasitaemia on productivity

Bodyweights at 12 and 24 months of age for animals born in the study were calculated by interpolation between the two closest recorded monthly weights within 60 days either side of each age. The proportion of times that an animal was detected parasitaemic between 13 and 24 months was calculated and coded into four parasitaemia classes: no detected parasitaemias during the 12 months, ≤0.25, >0.25 and ≤0.50, and >0.50 of the samples parasitaemic. An analysis of variance to determine the effect of parasitaemia on weight gain between 13 and 24 months of age and including parameters for herd, sex, year of birth, season of birth and year × season was undertaken for calves born between 1986 and 1989.

An analysis of variance was also undertaken to determine the effect of parasitaemia on calving interval, fitting effects of herd, year of calving (1986–1989), season of calving, year × season, parity, bodyweight and change in bodyweight post partum and whether or not the calf was born alive. Four classes of parasitaemia were included as before to define the proportions of times that cows were parasitaemic during the first five months post partum. The effect of parasitaemia as a cause of abortion was analysed by classifying cows as to whether they were detected parasitaemic or not at least once during the last three months of pregnancy. A logistic model (GLIM Release 3.77, Royal Statistical Society,
was then fitted to the proportions of live births classified by herd, year of calving (1986–1991), season of calving, season × year and parasitaemia class (yes, no).

**Associations between PCV and productivity**

A cohort of 108 14–20-month-old calves was chosen and their growth rates between March and September 1989 calculated. Growth rate during this period, which covered the wet season, was approximately linear. Growth rates were analysed by analysis of variance fitting parameters for herd, sex, month of birth, parasitaemia class, treatment class, and with covariate terms for PCV (averaged over the period) within parasitaemia class. Four parasitaemia classes were defined as before. Likewise four treatment classes were defined for frequency of treatment: not treated, treated \( \leq 0.25 \), \( >0.25 \) and \( \leq 0.50 \), and \( >0.50 \) of the time.

Mean PCVs were also calculated for cows, both during the first five months of lactation and during the last three months of pregnancy. The analyses of variance described above were extended to include treatment class and PCV within parasitaemia class as a covariate.

**Offspring-dam regressions**

Offspring-dam regressions were undertaken to determine the levels of associations between calves and their dams in PCV and frequency of parasitaemia. For this analysis five age groups were defined: –30 to 120, 121 to 300, 301 to 480, 481 to 660 and 661 to 840 days of age on the first day of the periods March-September (wet season) and September-March (dry season), 1986–1991. Separate offspring-dam regressions were fitted for each age group. In order to do this, corresponding mean values of PCV, frequency of parasitaemia and frequency of treatment were calculated for each calf’s dam, matching exactly the period when values had been calculated for the calf. Analyses of variance for mean PCV and square root of frequency of parasitaemia were then undertaken for cows, fitting parameters for year, season, year × season, herd, herd × year, herd × season, age, age × season and, for PCV, parasitaemia and treatment class. The same model was fitted for calves with additional terms for sex and sex × season. Calf and dam data were then corrected independently for all fixed effects. Using the corrected data, mean values were then calculated for each dam and her offspring within each age group and offspring-dam regression analyses undertaken, weighted by the number of offspring per dam.

**RESULTS**

**Effect of Parasitaemia on Productivity**

Trypanosome infection in the calf significantly affected growth rate between 13 and 24 months of age \( (P < 0.01) \) (Table 1). Nineteen animals found to be parasitaemic on more than half the occasions between 13 and 24 months of age had a mean liveweight gain of
42.5 ± 3.9 kg which was 15.5 ± 4.6 kg (27%) less than that of 79 animals not detected parasitaemic over the period. This effect of parasitaemia on weight gain was transient, however, since, when actual bodyweights at 24 and 36 months (data not shown) were analysed in relation to the frequency of parasitaemia over the previous 12 months, no significant relationships were found.

A significant effect of the proportion of time detected parasitaemic during the first five months of lactation on calving interval was also found (P < 0.01) (Table 2). Cows detected parasitaemic for more than half the period had a mean calving interval 41 days longer on average than for cows not detected parasitaemic. The percentage of calvings resulting in abortions was also related to the occurrence of parasitaemia during the last three months of pregnancy (P = 0.05). The percentage of abortions increased from 6.8 to 10.1% when cows detected parasitaemic at least once during the last three months of pregnancy were compared with cows not detected parasitaemic over this period.

Table 1. Proportions of time calves parasitaemic between 13 and 24 months of age and effects on calf bodyweight gain.

<table>
<thead>
<tr>
<th>Proportion of time detected parasitaemic</th>
<th>No. of calves</th>
<th>Body weight gain 13–24 months (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>79</td>
<td>58.0 ± 2.2</td>
</tr>
<tr>
<td>≤ 0.25</td>
<td>206</td>
<td>55.0 ± 1.5</td>
</tr>
<tr>
<td>≤ 0.50</td>
<td>90</td>
<td>50.5 ± 1.9</td>
</tr>
<tr>
<td>&gt; 0.50</td>
<td>19</td>
<td>42.5 ± 3.9</td>
</tr>
</tbody>
</table>

Table 2. Proportions of time cows parasitaemic 0–5 months post partum and effects on calving interval.

<table>
<thead>
<tr>
<th>Proportion of time detected parasitaemic</th>
<th>No. of intervals</th>
<th>Mean calving interval (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>170</td>
<td>449 ± 13</td>
</tr>
<tr>
<td>≤ 0.25</td>
<td>152</td>
<td>469 ± 14</td>
</tr>
<tr>
<td>≤ 0.50</td>
<td>125</td>
<td>471 ± 15</td>
</tr>
<tr>
<td>&gt; 0.50</td>
<td>102</td>
<td>490 ± 15</td>
</tr>
</tbody>
</table>

Associations between PCV and Productivity

The results of analysis of the cohort of 14–20-month-old animals born between October 1987 and April 1988 are shown in Table 3. Although the regression coefficients of growth rate on PCV appeared to be somewhat variable between parasitaemia classes, the interaction was not significant. The average regression of growth rate on PCV (14.6 ± 4.4 g/d/% unit) was significant (P < 0.01).
When mean PCV measured over the first five months of lactation was added to the analysis of variance model for calving interval, a significant regression coefficient of –8.4 ± 2.6 d/% unit was found (P < 0.01). Thus, there was an average reduction of 8.4 days in calving interval for each % unit increase in PCV.

Mean PCV maintained during the last three months of pregnancy was also significantly associated with risk of abortion. When corrected for parasitaemia and treatment class, a regression coefficient of 0.8 ± 0.3 % unit decrease in abortion rate per % unit increase in PCV maintained among cows detected parasitaemic was found (P < 0.01).

Offspring-dam Regression

Offspring-dam regression coefficients for PCV and frequency of parasitaemia measured in dams and offspring over the same time periods are given in Table 4. Except for the youngest calves, regression coefficients for PCV showed a slightly increasing trend with age (Table 4). The mean regression coefficient for animals in the oldest two age groups was 0.20 ± 0.08. Significant regression coefficients were also obtained for frequency of parasitaemia with a mean of 0.12 ± 0.06.

DISCUSSION

Effect of Parasitaemia on Productivity

There were significant effects of trypanosomiasis on productivity. However, for growth, the effect tended to be transient and, for calving interval, the effect was small. Indeed, the average reduction in liveweight gain between 13 and 24 months of age was not as large as that demonstrated by Trail et al. (1991a) in untreated post-weaner N’Dama cattle in Gabon. The difference in calving interval of 41 days, found when cows detected parasitaemic on more than half the occasions were compared with cows not detected parasitaemic, was also

Table 3. Regression coefficients of growth rates between March and September, 1989 on PCV in 14–20-month-old animals, adjusted for year and month of birth, herd, sex and treatment.

<table>
<thead>
<tr>
<th>Proportion of time detected parasitaemic</th>
<th>No. of animals</th>
<th>Regression coefficient (g/d/unit %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>37</td>
<td>9.1 ± 5.5</td>
</tr>
<tr>
<td>≤ 0.25</td>
<td>33</td>
<td>0.8 ± 5.3</td>
</tr>
<tr>
<td>≤ 0.50</td>
<td>28</td>
<td>9.4 ± 7.0</td>
</tr>
<tr>
<td>0.50</td>
<td>10</td>
<td>39.1 ± 13.4</td>
</tr>
<tr>
<td>Mean</td>
<td>108</td>
<td>14.6 ± 4.4</td>
</tr>
</tbody>
</table>

When mean PCV measured over the first five months of lactation was added to the analysis of variance model for calving interval, a significant regression coefficient of –8.4 ± 2.6 d/% unit was found (P < 0.01). Thus, there was an average reduction of 8.4 days in calving interval for each % unit increase in PCV.

Mean PCV maintained during the last three months of pregnancy was also significantly associated with risk of abortion. When corrected for parasitaemia and treatment class, a regression coefficient of 0.8 ± 0.3 % unit decrease in abortion rate per % unit increase in PCV maintained among cows detected parasitaemic was found (P < 0.01).
smaller than that reported in infected, untreated N’Dama cattle. Trail et al. (1991b) found that cows parasitaemic for an average of as little as 13% of the calving interval in Zaire had a calving interval 68 days longer than for cows not detected parasitaemic. Occurrence of a trypanosome infection during the first four months of lactation increased average calving interval from 581 to 651 days in village cattle in The Gambia (Agyemang et al., 1993).

The most significant effects of trypanosomiasis appeared to be on calf mortality (data not shown) and foetal mortality. The average rate of abortion was high, an estimated 8.4% of all calvings, and a significant proportion of these appeared to be associated with incidence of parasitaemia.

Despite significant levels of drug resistance, the results of these statistical analyses showed that regular trypanocidal treatment appeared to maintain satisfactory levels of cattle productivity. Whilst not eliminating infections, therefore, Berenil treatment appeared, in some way, to be limiting parasite growth.

Associations between PCV and Productivity

The associations between PCV, corrected for frequency of parasitaemia and treatment, and growth and calving interval agree with findings in N’Dama cattle (Trail et al., 1991a, 1991b). The cohort of animals chosen during a period of high trypanosome prevalence demonstrated a significant association between PCV and growth rate. The ability of an animal to resist development of anaemia when parasitaemic was found by Trail et al. (1991a) to be associated with a growth rate higher than that of a contemporary unable to resist development of anaemia. Whilst the concept of an ability to resist development of anaemia cannot be applied to these East African zebu cattle, since eventually all animals required treatment at some time or other, the ability of some animals to maintain, under treatment, higher PCVs than their contemporaries appeared, nevertheless, to make them less susceptible to the effects of trypanosomiasis.

### Table 4. Offspring-dam regression coefficients for PCV, and frequency of parasitaemia calculated from dam and offspring values measured over the same six-month periods.

<table>
<thead>
<tr>
<th>Calf age group (days)†</th>
<th>Average age (months)</th>
<th>No. of dams</th>
<th>Regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCV‡</td>
</tr>
<tr>
<td>–30 to 120</td>
<td>4</td>
<td>334</td>
<td>0.12 ± 0.10</td>
</tr>
<tr>
<td>121 to 300</td>
<td>9</td>
<td>360</td>
<td>0.05 ± 0.05</td>
</tr>
<tr>
<td>301 to 480</td>
<td>15</td>
<td>300</td>
<td>0.10 ± 0.05</td>
</tr>
<tr>
<td>481 to 660</td>
<td>21</td>
<td>240</td>
<td>0.22 ± 0.07</td>
</tr>
<tr>
<td>661 to 940</td>
<td>27</td>
<td>180</td>
<td>0.18 ± 0.08</td>
</tr>
</tbody>
</table>

*calculated using square root of frequency of parasitaemia.
†age at start of six-month period from 1 March or 1 September.
‡corrected for parasitaemia and treatment.
The association between PCV and calving interval also agrees with findings in N’Dama cattle (Trail et al., 1991b). N’Dama cows that were able to maintain higher than average PCVs despite parasitaemia had calving intervals on average 59 days shorter than for cows with lower than average PCVs. In the present study this productivity-linked ability to maintain PCV was also apparent in terms of risk of abortion. The high levels of drug resistance resulting in frequent treatments with diminazene acetate make interpretation of these data difficult because of the confounding of parasitaemia and treatment. Nevertheless the results indicate a degree of variation in susceptibility of these cows to the effects of trypanosomiasis on reproduction.

Offspring-dam Regressions

It was of interest to investigate whether there were genetic associations in this apparent productivity-linked ability to maintain PCV. Sires were not known in this village environment. Thus, the only possibility was to compare offspring with their dams. Significant regression coefficients for PCV, corrected for parasitaemia and treatment, were obtained. An increase in value with age was opposite to the trend that might have been expected in the presence of a significant maternal influence. Thus, the maternal influence on calf PCV appeared to be negligible and the ability to maintain PCV under the stress of infection appeared, to some extent, to be an acquired trait.

Significant regression coefficients were also obtained for frequency of detected parasitaemias. These regression coefficients did not change with age, again indicating a lack of maternal influence. However, they need careful interpretation. Rowlands et al. (1993) showed that at least a third of detected parasitaemias were due to recurrent, not new infections. Thus, these offspring-dam regression coefficients may be reflecting a genetic covariance in the way animals control parasitaemia in long-standing infections rather than in their susceptibility to new infections.

If maternal effects can be ignored, then multiplication of offspring-dam regression coefficients by 2 gives estimates of co-heritability. The term co-heritability, rather than heritability, is used since the traits being compared are measured at different ages. If the genetic correlation between dam and offspring PCV, however, is close to 1, then the co-heritability estimate may be assumed to approximate to the heritability itself. Otherwise, it will be an underestimate. The increase in regression coefficients with age for PCV suggests that by two years of age the genetic correlation between a dam’s and her offspring’s ability to maintain PCV may have approached 1. Multiplying the mean regression coefficient calculated for the two oldest age groups (Table 4) by two gives an estimate of heritability of 0.40 ± 0.16. This estimate is in the range of other heritabilities reported in the literature for PCV (e.g. Kitchenham and Rowlands, 1976; Rowlands et al., 1974, 1983; Trail et al., 1991c).

In conclusion, within this environment at Ghibe where animals have been regularly treated with diminazene acetate in a situation of high prevalence of drug resistance, there was evidence of genetic variation in animal susceptibility to the effects of trypanosomiasis. Further, animals maintaining higher than average PCV showed superior productivity to those with lower than average PCV. Studies of trypanosusceptible breeds of cattle in other...
more suitable environments would be of value in assessing further the extent of this apparent variation in individual animal susceptibility to the effects of trypanosomiasis.

REFERENCES


