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RELATIONSHIPS BETWEEN TSETSE CHALLENGE AND TRYPANOSOME PREVALENCE IN TRYPANOTOLERANT AND SUSCEPTIBLE CATTLE

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Abstract—The relationships between estimates of tsetse challenge and trypanosome prevalence in trypanotolerant and susceptible cattle were examined at sites of the African Trypanotolerant Livestock Network. Estimates of tsetse challenge were determined as the product of tsetse relative densities, their trypanosome infection rates and the proportions of feeds taken by them from cattle. Trypanosome prevalence in both trypanotolerant and susceptible breeds of cattle was estimated from monthly examination of groups of ear-tagged cattle. Regression equations between estimates of trypanosome prevalence and tsetse challenge were fitted using an arcsin transformation of trypanosome prevalence and a $\log_{10}$ transformation of tsetse challenge. Highly significant relationships between estimates of tsetse challenge and trypanosome prevalence were found for sites with trypanotolerant cattle ($P < 0.0001$) and sites with susceptible cattle ($P < 0.01$). Mean trypanosome prevalence at a given level of tsetse challenge was at least twice as high in susceptible as in trypanotolerant cattle. The slopes of the regression lines for the two groups of cattle were significantly different ($P < 0.05$). The results confirm the superior ability of trypanotolerant cattle to withstand tsetse challenge in the field. The curves obtained for the two groups of cattle illustrate the necessity in tsetse control campaigns for a major reduction of tsetse populations to take place before significant decreases in trypanosome incidence in livestock can be achieved.

Key Words: Tsetse, *Glossina*, tsetse challenge, trypanosomiasis, trypanotolerance

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Résumé—Les relations entre les estimations de la pression glossinaire, et la prévalence trypanosomienne chez le bétail trypanotolérant et trypanosensible ont été examinées sur les sites du Réseau Africain d'Etudes du Betail Trypanotolerant. Une estimation de la pression glossinaire a été obtenue en calculant le produit de la densité relative de tsétsés, du taux d'infection trypanosomienne, et de la proportion de repas de sang pris sur le bétail. La prévalence trypanosomienne chez le bétail a été obtenue par l'examen parasitologique mensuel de groupes d'animaux identifiés par boucle auriculaire. Les équations de régression entre les estimations de la prévalence trypanosomienne et la pression glossinaire ont été déterminées aprés transformation logarithmique de la pression glossinaire ($\log_{10}$) et transformation arcsin de la prévalence trypanosomienne. Il existe une relation hautement significative entre les estimations de la pression glossinaire et la prévalence trypanosomienne dans les sites du Réseau comportant du bétail trypanotolérant ($P<0.0001$) et dans les sites comportant des animaux sensibles ($P<0.01$). La prévalence trypanosomienne moyenne pour un niveau donné de pression glossinaire est au moins deux fois plus élevée chez le bétail sensible que chez le bétail résistant. Les pentes des équations de régression pour les deux types de bétail sont significativement différentes ($P<0.05$). Ces résultats confirment la capacité du bétail trypanotolérant de supporter la pression glossinaire naturelle. Les courbes obtenues pour les deux groupes d'animaux illustrent la nécessité d'une réduction considérable de la population glossinaire au cours des campagnes de lutte, pour qu'un effet significatif sur l'incidence des trypanosomoses chez le bétail soit obtenu.

INTRODUCTION

Large areas of Africa are unsuitable for livestock production due to the presence of tsetse (Murray and Gray, 1984) and in some tsetse infested areas of west and central Africa only trypanotolerant breeds of domestic livestock can be kept without chemoprophylaxis. The African Trypanotolerant Livestock Network (ATLN) was established following an ILCA/FAO/UNEP survey of trypanotolerant cattle, the results of which were published in 1979 (ILCA/FAO/UNEP, 1979). The ATLN is a collaborative research Network, established by the International Livestock Centre for Africa (ILCA) together with the International Laboratory for Research on Animal Diseases (ILRAD) and national research organizations. The aim of the network is to determine the productivity of trypanotolerant livestock under different management systems, in different ecological zones and under quantified levels of tsetse challenge or trypanosomiasis risk. The data allow the productivity of trypanotolerant cattle to be compared with that of susceptible breeds and are intended to provide a basis for improved management of cattle in tsetse affected areas of Africa. The estimation of tsetse challenge and of trypanosome prevalence in cattle is necessary to permit such comparisons to be made. Results showing relationships between tsetse challenge and trypanosome prevalence in trypanotolerant and susceptible breeds of cattle are reported here.

MATERIALS AND METHODS

Study sites

Data reported here were collected from studies conducted at seven sites of the African Trypanotolerant Livestock Network. Descriptions of the sites, their management systems and domestic livestock have been given previously (ILCA, 1986a, 1986b; ILCA/ILRAD, 1988). The sites with trypanotolerant N'Dama cattle were a state ranch of the Office Gabonais d'Amelioration et de Production de Viande (OGAPROV) in Gabon, and a commercial ranch at Mushie in Zaire, where research work has been carried out since 1984, and at village herds in the Idiofa area of Zaire where studies began in 1986. The Idiofa site was split into two sub-sites, forest and plateau. At sites with susceptible Zebu cattle studies commenced in 1984 at Boundiali and Tengrela in Côte d'Ivoire and in 1986 at the Ghibe and Tolley sites in Ethiopia.

Tsetse surveys

Details of the methods used for determination of tsetse density, their trypanosome infection rates and their feeding preferences and trypanosome prevalence in domestic livestock have been described previously (ILCA, 1986a, 1986b; ILCA/ILRAD, 1988).

Briefly, relative densities of tsetse were determined from catches in biconical traps (Challier and Laveissiere, 1973) and are expressed as the number of flies caught per trap per day. Trapping was carried out for approximately 1 week per month, cages being emptied daily. As far as possible, trapping was carried out where tsetse/cattle contact was likely to occur, as established by preliminary surveys at each site. The proboscides, midguts and salivary glands of live tsetse were dissected and examined under phase contrast microscopy for determination of trypanosome infection rates and types using the method of Lloyd and Johnson (1924). Feeding preferences of tsetse were determined by identifying the origin of residual undigested bloodmeals in their midguts. Analyses were carried out using an ELISA technique described by Rurangirwa et al. (1986).

Determination of trypanosome prevalence in cattle

Groups of ear-tagged cattle were bled once per month from 1984 to 1987 at the sites in Côte d'Ivoire and at the OGAPROV and Mushie ranches, and from 1986 to 1987 at Idiofa and the Ghibe and Tolley sites. The presence of trypanosomes in the blood was determined by haematocrit centrifugation and examination of the buffy coat using phase contrast microscopy (Murray et al., 1977). Identification of trypanosome species was from thin blood smears stained with Giemsa and from wet preparations of the buffy coat. These data were collected simultaneously with the collection of entomological data.

Data analysis

Tsetse challenge was estimated simply as the proportion of infected tsetse feeding upon livestock in the study, and was calculated as the product of tsetse relative density, mature trypanosome infection rates in those tsetse and the proportion of feeds taken by them from cattle.

Preliminary analyses indicated that trypanosome prevalence might be related to tsetse challenge in a curvilinear manner. A $\log_{10}$ transformation of tsetse challenge was therefore chosen as the most appropriate method to make the data suitable for linear regression analysis. An arcsin transformation of trypanosome prevalence was used to stabilize variance (Snedecor and Cochrane, 1980).

RESULTS

Tsetse challenge

At some sites, bloodmeals suitable for analysis could only be obtained for the most abundant species. Tables 1 and 2 show the estimates of tsetse

Table 1. Tsetse challenge and trypanosome prevalence in N'dama cattle at three Network sites

	Zaire			Gabon
	Mushie	Idiofa (F)	Idiofa (P)	OGAPROV
1984				
Tsetse challenge	606.1	–	–	89.1
Trypanosome prevalence	6.6	–	–	4.4
1985				
Tsetse challenge	8275.4	–	–	133.7
Trypanosome prevalence	10.8	–	–	5.0
1986				
Tsetse challenge	3671.3	28.3	13.4	81.6
Trypanosome prevalence	12.8	5.1	1.1	6.3
1987				
Tsetse challenge	2503.3	16.0	6.7	63.4
Trypanosome prevalence	7.8	3.3	2.0	5.8

F = Forest.
P= Plateau.

Table 2. Tsetse challenge and trypanosome prevalence in Zebu cattle at four Network sites

	Ethiopia		Côte d'Ivoire	
	Tolley	Ghibe	Boundiali	Tengrela
1984				
Tsetse challenge	–	–	798.3	298.1
Trypanosome prevalence	–	–	22.1	3.1
1985				
Tsetse challenge	–	–	661.4	90.0
Trypanosome prevalence	–	–	11.1	3.3
1986				
Tsetse challenge	1756.8	108.1	2337.4	20.9
Trypanosome prevalence	22.1	20.8	23.0	1.4
1987				
Tsetse challenge	2746.9	193.6	–	–
Trypanosome prevalence	21.0	15.2	–	–
1988				
Tsetse challenge	2497.9	425.5	–	–
Trypanosome prevalence	26.3	24.0	–	–

challenge at sites with susceptible and trypanotolerant breeds respectively. The data on trypanosome infection rates, relative densities and proportions of feeds taken from cattle,which were used to determine tsetse challenge, are reported by Leak et al. (1989).

Trypanosome prevalence in cattle

Table 1 shows the annual estimates of mean monthly trypanosome prevalence detected at three sites with N'Dama cattle. These were low at Idiofa and high at Mushie relative to the prevalences detected in N'Damas at the other sites of the Network (Leak et al., 1988).

Table 2 shows estimates of trypanosome prevalence in susceptible Zebu cattle, these were higher than in N'Dama cattle.

Relationship between tsetse challenge and trypanosome prevalence in cattle

Analysis of the transformed data showed a significant regression of trypanosome prevalence on tsetse challenge for both susceptible and trypanotolerant breeds of cattle. Figure 1 shows the results from sites with trypanotolerant cattle with a highly significant relationship ($P < 0.0001$) and the data points fitting well to the regression line ($r = 0.90$). Figure 2 shows results at sites with susceptible cattle, the relationship was less significant ($P < 0.01$) than with trypanotolerant cattle ($r = 0.74$).

A "*t*-test" showed that the slopes for the two regression equations were significantly different ($P<0.05$), that of susceptible cattle being more than twice that of trypanotolerant cattle. Detransformation of these equations back to the original scale (Fig. 3) shows the predicted

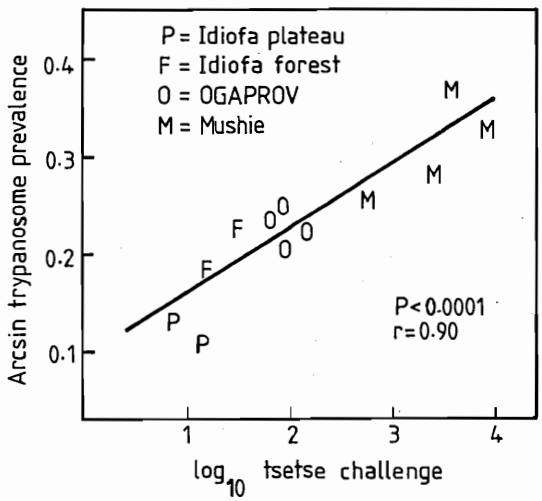

Fig. 1. Relationship between transformed tsetse challenge and trypanosome prevalence in trypanotolerant N'Dama cattle.

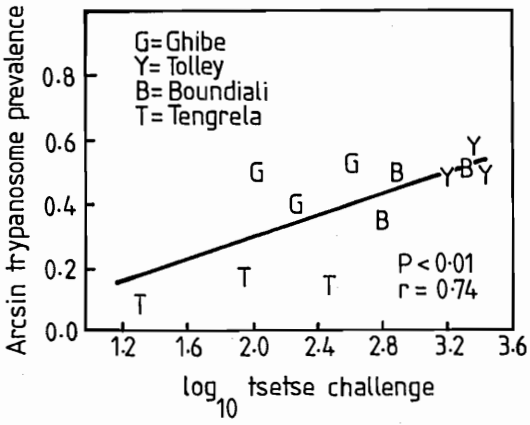

Fig. 2. Relationship between transformed tsetse challenge and trypanosome prevalence in susceptible Zebu cattle.

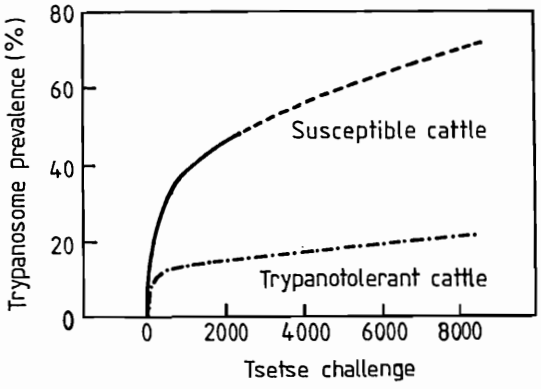

Fig. 3. The predicted relationships between tsetse challenge and trypanosome prevalence in susceptible and trypanotolerant breeds of cattle from the respective regression equations. The dashed extension to the curve for susceptible cattle is an extrapolation beyond the range of tsetse challenge at sites in this study.

relationships between tsetse challenge and trypanosome prevalence for the two cattle breeds. The mean trypanosome prevalence at a given level of tsetse challenge was at least twice as high in susceptible as in trypanotolerant cattle.

DISCUSSION

The data for components of the model were collected under field conditions with minimum basic equipment and limited manpower. Typically, a team consisting of a veterinarian and two or three technicians was responsible for monitoring disease and productivity parameters in cattle, as well as tsetse population parameters. The fact that significant relationships between trypanosome prevalence and tsetse challenge were detected suggests that the methods employed were sufficient under these conditions to evaluate the two parameters.

The difference between the curves shown in Figure 3 demonstrates the ability of trypanotolerant cattle to exist at a given level of tsetse challenge with significantly lower rates of trypanosome prevalence than susceptible breeds, particularly when tsetse challenge is high. In trypanotolerant cattle, trypanosome prevalence appears to rise steeply to about 10% at a relatively low level of tsetse challenge and then continues to rise more gradually. Trypanosome prevalence in susceptible breeds rises more steeply throughout, with increasing tsetse challenge. These relationships have important implications for the impact of tsetse control campaigns. It would appear that in situations with relatively high tsetse challenge a 90–95% reduction in tsetse challenge may not lead to a significant reduction in trypanosome prevalence. This would particularly be the case for trypanotolerant cattle. The results of tsetse control campaigns have frequently reported effects on tsetse populations alone. It has thus been difficult to fully evaluate such campaigns. A tsetse control campaign using cypermethrin-impregnated biconical tsetse traps currently underway in the Boundiali Network site in northern Côte d'Ivoire has been designed to allow a full evaluation of the reduction in tsetse populations and its effect on trypanosome prevalence and productivity of livestock in the region (Coulibaly et al., 1989).

Limitations of the model

Accurate modelling for quantification of tsetse challenge or trypanosomiasis risk is complex with many factors affecting the three most important components: tsetse distribution and abundance, trypanosome infection rates in tsetse and the proportion of feeds taken by them from domestic livestock. These factors have been listed by various authors (Molyneux, 1977; Jordan, 1986; Whiteside, 1958). Among the most important of these are: vectorial capacity (transmission coefficients), trap efficiency, estimation of trypanosome infection rates in tsetse, and factors such as drug resistance and chemotherapy, which affect reliability of estimates of trypanosome prevalence. Monthly examination of cattle is not a satisfactory method of estimating trypanosome prevalence, due to the fluctuating levels of parasitaemia, which may become undetectable.

The model described here does not take into account all factors determining whether or not a tsetse fly will transmit trypanosomes to cattle. Similarly, it does not consider factors affecting the reliability of estimates of both tsetse challenge and trypanosome prevalence in cattle. However, the close relationship between tsetse challenge and trypanosome prevalence suggests that corrections for trap efficiency or transmission coefficients of tsetse, for example, may not change estimates significantly. Thus, one can estimate tsetse challenge in the field, simply, in this way.

It would nonetheless be desirable to take some of these factors into account when feasible. Mark-release-recapture experiments could provide an indication of trap efficiency for the different species of tsetse allowing correction factors to be used for improving between site comparisons. Assumptions would still need to be made regarding the validity of such correction factors, as efficiency of traps may vary, even for the same species from site to site, or seasonally. Some data on the vectorial capacity or transmission coefficients of tsetse are available for some tsetse and trypanosome species. These transmission coefficients may differ for the same species in different sites however.

The results presented here suggest that tsetse challenge can be estimated simply, in the field. The superior ability of trypanotolerant cattle to withstand tsetse challenge was demonstrated. The results show the necessity for high levels of reduction of tsetse populations in order to achieve significant reductions in trypanosome prevalence in cattle.

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REFERENCES

Coulibaly L. (1989) Effects of tsetse control on trypanosome prevalence in cattle. *International Scientific Council for Trypanosomiasis Research and Control, Twentieth Meeting* Mombasa (In press).

Challier A. and Laveissiere C. (1973) Un nouveau piége pour la capture des glossines, description et essais sur le terrain. *Cah. ORSTOM Sér. Entomol. Méd. Parasitol.* 11, 251–262.

ILCA (1986a) *The ILCA/ILRAD Trypanotolerance Network Situation Report* December 1985. Proceedings of a Network Meeting held at Nairobi. ILCA, Addis Ababa. pp. 98.

ILCA (1986b) The African Trypanotolerant Livestock Network. Indications from results, 1983–1985. ILCA, Addis Ababa. pp. 138.

ILCA/ILRAD (1988) Livestock Production in Tsetse Affected Areas of Africa. ILCA/ILRAD Nairobi. pp. 473.

ILCA/FAO/UNEP (1979) *Trypanotolerant Livestock in West and Central Africa* Vol. 1, Monograph 2. Addis Ababa, ILCA.

Jordan A. M. (1986) *Trypanosomiasis Control and African Rural Development.* Longman, London and New York.

Leak S. G. A., Awuome K., Colardelle C., Duffera W., Feron A., Mahamat B., Mawuena K., Minengu M., Mulungo M., Nankodaba G., Ordner G., Sheria M., Tikubet G., Toure M. and Yangari G. (1988) Determination of tsetse challenge and its relationship with trypanosome prevalence in trypanotolerant livestock at sites of the African Trypanotolerant Livestock Network. In *Livestock Production in Tsetse Affected Areas of Africa.* ILCA/ILRAD Nairobi. pp. 43–54.

Leak S. G. A., Colardelle C., Coulibaly L., Dumont P., D'Ieteren G., Jeannin P., Feron A., Hecker P. A., Maloo S., Minengu M., Minja S. H., Mulungo M., Mulatu W., Nankodaba M., Ngamuna S., Ordner G., Schuetterle A., Sauveroche B., Tikubet G., Trail J. C. M., Toure M., Tsotsi E., and Yangari G. (1989) In *Tsetse Feeding Habits and Tsetse Challenge at Sites of the African Trypanotolerant Livestock Network.* International Scientific Council for Trypanosomiasis Research and Control 20th meeting, Mombasa, 1989.

Lloyd L. L. and Johnson W. B. (1924) The trypanosome infections of tsetse flies in northern Nigeria and a new method of estimation. *Bull. entomol. Res.* 14, 265–288.

Molyneux D. H. (1977) Vector relationships in the Trypanosomatidae. *Adv. Parasitol.* 15, 1–82.

Murray M., Murray P. K. and McIntyre W. I. M. (1977) An improved parasitological technique for the diagnosis of African trypanosomiasis. *Trans. R. Soc. Trop. Med. Hyg.* 71, 325–326.

Murray M. and Gray A. R. (1984) The current situation on animal trypanosomiasis in Africa. *Prev. Vet. Med.* 2, 23–30.

Rurangirwa F. R., Minja S. H., Musoke A. J., Nantulya V. M., Grootenhuis J. and Moloo S. K.

(1986) Production and evaluation of specific antisera against sera of various vertebrate species for identification of blood meals of *Glossina morsitans centralis*. *Acta tropica* 43, 379–389.

Snedecor G. W. and Cochrane W. G. (1980) *Statistical Methods*. 7th edition. Iowa city: Iowa State University Press.

Whiteside E. F. (1958) The Maintenance of Cattle in Tsetse-Infected Country. International Scientific Council for Trypanosomiasis Research, Brussels, pp. 83–90.