Rev. Brasil. Genet. VIII, 2, 361-375 (1985)
(Brazil. J. Genetics)

CAUSES OF VARIATION OF FIELD BURDENS OF CATTLE TICKS (*B. microplus*)

F.E. Madalena[1,2], R.L. Teodoro[1], A.M. Lemos[1] and G.P. Oliveira[3]

ABSTRACT

Tick counts were made on 18 occasions on 215 female cattle of six red and white Holstein-Friesian (HF): Guzera (G) breed groups. There were 506 observations on 142 animals sired by 25 HF bulls, 90 observations on 30 animals sired by 7 bulls of 5/8 HF: 3/8 G grade and 141 observations on 43 animals sired by 12 G bulls. Semi engorged female ticks, 4.5 to 8.0 mm long, were counted on the right side of the animal. Spraying with acaricides was withheld before tick counts for at least 33 and on average 67 days. All animals assessed at each date of counting were contemporaries together in the same pastures. Some animals were assessed more than once. There were 357 observations on heifers and 380 observations on milking cows. Data transformation, log (2 x count+1), reduced skewness and kurtosis and resulted in homogeneous variances within grade x counting occasion cells. Effects of age within counting occasion, days pregnant and days on milk were not significant ($P > 0.10$). Correlation between counts on the same animal at different occasions was 0.40 when counts were made in spring/summer, 0.39 when counts were made in autumn/winter and 0.24 when counts were made in different seasons. Too low or too high tick burdens decreased these correlations, the maximum value being expected at a burden of 185 ticks per animal. Long intervals between counts reduced the correlation. Correlations were not affected by category (heifer or cow) when time interval between counts was included in the model. Culling ten percent most infested heifers would be expected to eliminate 18 percent of the tick population in HF animals. This latter proportion increased with Zebu grade up to 26 percent in 1/4 HF: 3/4 G animals. Heritability of transformed tick counts for the progeny of HF sires was

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[1] EMBRAPA, Centro Nacional de Pesquisa de Gado de Leite (CNPGL), 36155 Coronel Pacheco, MG, Brasil. Send correspondence to F.E.M.

[2] Convênio IICA/EMBRAPA.

[3] UEAPE, EMBRAPA, 13560 São Carlos, SP, Brasil.

$h^2 = 0.201 \pm 0.064$. Negative estimates for sire components of variance were obtained for progeny of crossbred and G bulls.

INTRODUCTION

The existence of genetic variation in the resistance of cattle to ticks (*Boophilus microplus,* Canestrini, 1887) has been known for a long time (Villares, 1941, Ulloa and De Alba, 1957) but only rather recently has this trait received consideration for selection purposes, mainly as a result of Australian research (reviews by Sutherst and Utech, 1982 and Lemos, 1984). Two new dairy breeds have been developed including tick resistance in the selection criterion: Australian Milking Zebu (Hayman, 1974) and Australian Friesian Sahiwal (Alexander *et al.,* 1983). Estimates of heritability, repeatability and effects of environmental factors on tick resistance are needed to design breeding plans for this trait. This paper reports some causes of variations of tick burdens under field conditions, utilizing data from a trial designed to evaluate crossbreeding strategies with European and Zebu breeds for dairy production (Madalena, 1981). Breed differences and heterotic effects were reported by Lemos *et al.* (1985).

MATERIAL AND METHODS

Animals and management

Females of six red and white Holstein-Friesian (HF): Guzera (G) breed groups were assessed for resistance to field infestations of ticks. Throughout this paper, breed group is defined as the expected fraction of HF genes, the implicit complement adding to one coming from the G breed. The six groups were: 1/4, 1/2, 5/8, 3/4, 7/8 and $\geqslant$ 31/32 of HF. Halfbreds (1/2) were F_1s out of G dams and HF sires. The 1/4s and 3/4s were first backcrosses of F_1 dams to, respectively, G and HF sires. The 7/8s were second backcrosses to HF sires and 5/8s were obtained by *inter se* matings of 5/8 sires and dams. Thus, HF bulls sired animals of 1/2, 3/4, 7/8 and HF groups. Numbers of bulls, progeny and observations are shown in Table I. Semen of HF and G sires was from commercial Brazilian artificial insemination companies. 5/8 sires were obtained from the same herd as the 5/8 dams. Further information on genetic background of these animals was given by Lemos *et al.* (1984) . Heifers were reared at Santa Mônica Experimental Station, Municipality of Valença, State of Rio de Janeiro. Climate was described by Lemos *et al.* (1984) and management by Teodoro *et al.* (1984). Cows were kept on a high plane of nutrition as described by Madalena *et al.* (1982).

Tick burdens were assessed by counting semi-engorged female ticks 4.5 to 8.0 mm long on the right side of the animal (Wharton and Utech, 1970). Animals were sprayed routinely with acaricides, but spraying was withheld for at least 33 days before tick resistance assessments (on average 67 days). Burdens of heifers were assessed on twelve occasions, ten at Santa Mônica and two at another experimental farm (UEPAE São Carlos, State of São Paulo) where some heifers had been transferred. Except for minor deviations, five heifers were assessed per group at the first ten countings, eight at the eleventh and two at the twelfth. All cows in milk at Santa Mônica were assessed, twice at 14 day intervals, on three occasions. All animals assessed at each date of counting were contemporaries, together on the same pastures. Further details on number and age of animals, dates of counting and mean tick burdens were given by Lemos *et al.* (1985).

Table I -Number of sires, progeny and observations (tick counts).

	Breed of sire		
	HF	5/8[a]	G
Sires	25	7	12
Progeny	142	30	43
Observations	506	90	141

[a] 5/8 Holstein Friesian: 3/8 Guzera.

Statistical analyses

Due to strong dependence of variance on mean, the transformation log (2 x count + 1) was used (Wharton *et al.,* 1970; Seifert, 1971). The relation between variance and mean was studied fitting the model $V = a M^b$ to the variances (V) and means (M) of the residual deviations from group x date of counting cell means. There were 108 cells (6 groups x 18 dates of counting). Normality of distributions of transformed and untransformed residuals was assessed by χ^2 tests. Homogeneity of variances within grade x date of counting cells was tested according to Scheffé (1959).

Effects of age, days pregnant and days in milk were studied by method of least squares analysis of variance according to the mathematical model:

$$Y_{ijk} = b_0 + G_i + s_{ij} + b_1 x_{1ijk} + b_2 x_{2ijk} + b_3 x_{3ijk} + e_{ijk}$$

utilizing the program of Harvey (1976), where Y_{ijk} represents the transformed tick count of the kth daughter of the jth sire within the ith group; G_i is the fixed effect of the ith group (i = 1, . . . , 6), s_{ij} the random effect of the jth sire within the ith group;

x_{1ijk} represents age, x_{2ijk} the number of days pregnant and x_{3ijk} the number of days in milk of the ijkth animal. The last two covariables were excluded from the model for heifer data. The above model was fitted separately for each date of counting, but sums of squares and degrees of freedom were pooled over these dates.

Correlations between transformed counts of the same animal at different dates of counting were obtained, after adjusting transformed counts for group effects using the constants reported by Lemos *et al.* (1985). Following Wharton *et al.* (1970), these correlations were transformed to z values (Fisher, 1958) which were analyzed by weighed least squares according to the following model:

$$z_{ijk} = b_0 + C_i + S_j + b_1 c_{1ijk} + b_2 c_{2ijk} + b_3 I_{ijk} + e_{ijk}, \text{ where}$$

C_i = 1, 2 or 3, respectively, for correlations between counts on heifers, between counts on heifers and counts on cows, and between counts on cows.

S_j = 1, 2 or 3, respectively, for correlations between counts made in autumn/winter, counts made in spring/summer, and counts made in different seasons.

c_{1ijk} and c_{2ijk} = respectively, the smaller and the larger average of transformed counts on both dates of counting corresponding to the ijkth correlation.

I_{ijk} = interval (days) between these two dates.

To study the consequences of culling on the population of ticks, a numerical description was sought of the distribution of ticks over the individuals of a herd. To this end, heifers were ranked by descending order on tick count (T_i) separately for each group and date of counting. The cumulative untransformed tick count for the ith heifer was expressed as a ratio (R_i) to the total tick population counted on the n animals of the same group and date of counting, i.e., $R_i = \sum_i^i T_i / \sum_i^n T_i$. R_i was then related to the cumulative frequency of individuals $p_i = \sum_i^i (1/n)$ using the expression $R_i = 1 - (1 - p_i)e^{-kp_i}$. Thus, R_i ranges between 0 ($p_i = 0$) and 1 ($p_i = 1$), the rate of approach to the latter value depending on the coefficient k. For $k = 0$, $R_i = p_i$, for a uniform distribution of counts.

As mentioned, in general n = 5 for all group x date of counting classes but the eleventh (n = 8) and twelfth (n = 2) dates of counting. Because of small numbers in the class, data from the twelfth date were not used in this part of the study. Data from the first and second counting also were deleted because tick burdens were too low (average of 15 and 18 ticks per animal, respectively) and culling would not be advisable at such low levels of infestation (K.B.W. Utech, personal communication). The k values in the above model were estimated separately for each group using the modified Gauss-Newton method (Draper and Smith, 1966) through the SAEST COMPUTER PROGRAMME (Pimentel *et al.*, 1982).

Estimates of heritability were obtained from half sib intraclass correlations separately for the progeny of HF, 5/8 and G sires. It was not possible to obtain variance components using methods 2 or 3 of Henderson through the computer program of Harvey (1976) due to confounding of sires and progenies with grade and date of counting. Deviations from average of group x date of counting were used instead. Unbiased variance components for sires (σ_s^2), animals within sires (σ_a^2) and repeated counts within animals (σ_w^2) were obtained from the following random effects model by a procedure described by Madalena (1985):

$$d_{ijk} = \mu + s_i + a_{ij} + e_{ijk}$$

where d_{ijk} represents the transformed count of the jth progeny of the ith sire on the kth group x date of counting class, expressed as a deviation from the class average; s_i represents the effect of the ith sire; a_{ij} the effect of its jth progeny and e_{ijk} a residual peculiar to the kth count on the ijth animal.

Heritability was estimated as $h^2 = 4\sigma_s^2/(\sigma_s^2 + \sigma_a^2 + \sigma_w^2)$ and intraclass correlation repeatability as $r = (\sigma_s^2 + \sigma_a^2)/(\sigma_s^2 + \sigma_a^2 + \sigma_w^2)$.

RESULTS AND DISCUSSION

Transformation

Estimates of a and b in $V = aM^b$ for untransformed data were a = 1.45 ± 0.24 and b = 1.76 ± 0.17. Wharton *et al.* (1970) reported $\hat{b} = 1.93$. Transformation did not completely eliminate dependence of variance on mean, the equation for transformed data being $V = 0.01\ M^{-0.92}$. However, the test for homogeneity of variances within grade x date of counting cells with 17 and 90 degrees of freedom, resulted in F = 1.43 ($P > 0.10$) for transformed data and F = 7.23 ($P < 0.01$) for untransformed data. On these grounds, homoscedasticity was assumed for inferences from analysis of variance.

Seifert (1971) pointed out that the log transformation also was needed to eliminate skewness of the untransformed count distribution. Distributions of residuals for transformed and untransformed counts are shown in Figure 1. Untransformed data showed marked departure from normality ($X_2^2 = 309.88$, $P < 0.005$), skewness being $\gamma_3 = 2.04$ and kurtosis $\gamma_4 = 49.92$. The distribution was made more nearly normal by log transformation. Although departure from normality continued to be significant ($X_5^2 = 25.36$, $P < 0.005$) skewness was reduced to $\gamma_3 = -0.55$ and kurtosis to $\gamma_4 = 4.64$.

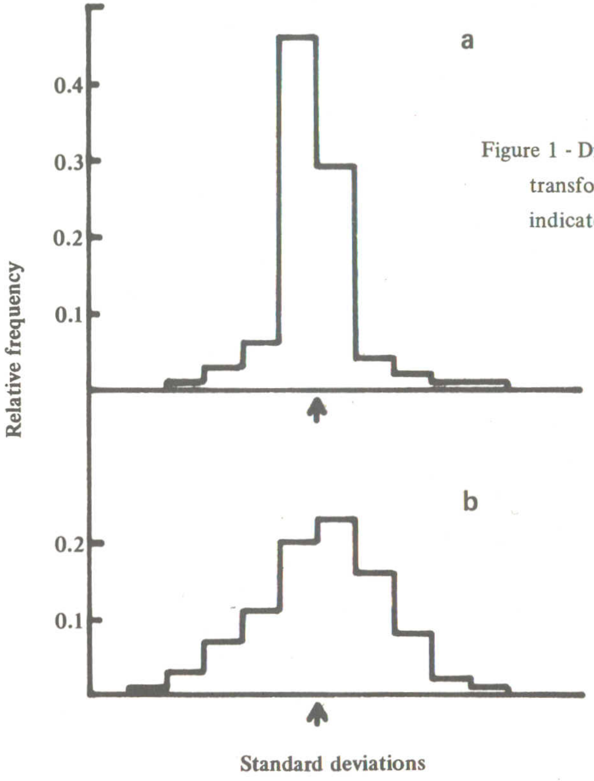

Figure 1 - Distribution of tick counts (a) untransformed, (b) transformed. The arrow indicates the sample mean.

Effects of age, pregnancy and lactation

Analyses of variance for log counts including age, days pregnant and days in milk as covariables are shown in Table II. None of these significantly affected log count ($P > 0.10$). Tick resistance is fully developed by cattle after they have been infected with a number of larvae of the order of 1.2×10^5 (Hewetson and Nolan, 1968; Hewetson and Lewis, 1976). The fact that age did not influence tick counts on heifers suggested that these animals would already have developed their potential resistance level. Mean age of heifers at each of the twelve dates of counting varied between 12 and 32 months, and age range varied between 3 and 18 months.

Mean age of cows at each of the six counting occasions varied between 40 and 52 months, age ranges being 12 months in all cases. The lack of significant age effects on tick count within this age range are in agreement with the results of Seifert (1971) and Utech *et al.* (1978a). The latter reported a decline of resistance for older cows.

Table II - Analysis of variance of transormed counts

	Heifers		Cows	
	d.f.	M.S.	d.f.	M.S.
Breed group	60	1.089**	30	1.818**
Sire/Group	146	0.180^{ns}	118	0.141^{ns}
Regression on				
Age	12	0.105^{ns}	6	0.165^{ns}
Days pregnant	–	–	6	0.255^{ns}
Days on milk	–	–	6	0.083^{ns}
Residual	127	0.179	208	0.183

**$P < 0.01$; ns, $P > 0.10$

Contradictory results have been reported on effects of pregnancy and lactation on tick burdens. Wharton *et al.* (1970) found that lactation increased burdens of Australian Illawarra Shorthorn cows, but burdens were not affected by pregnancy status. However, Utech *et al.* (1978a) found that both pregnancy and lactation reduced tick resistance in the same breed of cattle. Seifert (1971) reported that lactation increased burdens of Shorthorn: Hereford but not of Zebu corssbred cows. Johnston and Haydock (1971) did not find effects of pregnancy on Droughtmaster cows nor effects of lactation on Herefords or Droughtmasters. The absence of pregnancy and lactation effects in the present results might perhaps be explained by the high plane of nutrition and the relatively low tick burden of the milking herd, ranging from 10 to 77 ticks per animal. O'Kelly and Seifert (1969) and Sutherst *et al.* (1983) showed that undernutrition decreased tick resistance and it is tempting to speculate that pregnancy and lactation would be more stressful for undernourished cows carrying a high tick burden.

Correlation between counts

Transformed correlations between pairs of counts were significantly affected by season of counting, tick burden and interval between dates of counting ($P < 0.05$) but not by animal category ($P > 0.10$). Category was significant ($P < 0.01$), however, when the regression on interval between dates of counting was dropped from the model. Correlations between counts on heifers and counts on cows were lower than correlations between counts on animals of the same category, but this effect was entirely explained by the larger associated time interval between dates of counting.

z values were reduced by 0.47 for each thousand days elapsing between dates of counting (Table III). The mean interval between pairs of dates was 405 days, with a minimum of 14 and a maximum of 1283 days. At mean values of the other variables included in the model, the expected correlation between counts 14 days apart would be $r = 0.49$, which would decrease to $r = -0.05$ for the maximum interval of 1283 days. However, the observed values for correlations between the three pairs of counts repeated on cows at 14 day intervals were $r = 0.79$, $r = 0.69$ and $r = 0.52$. Sutherst *et al.* (1979) reported that differences between two groups of cows separated on high and low tick resistance decreased with time, whereas Hewetson and Lewis (1976) found that rankings of eight animals were very repeatable ($r = 0.68$ to 0.96) after 1.5 to 4 years.

Correlations between counts made in the same season were higher than correlations between counts made in different seasons (Table III). Wharton *et al.* (1970) found higher repeatabilities for summer counts ($r = 0.52$) than for winter counts ($r = 0.27$) and for counts made in different seasons ($r = 0.33$).

The regression of z on c_1 was positive, whereas the regression on c_2 was negative (Table III). Wharton *et al.* (1970) reported that an increase in mean tick burden from 6 to 200 ticks per animal corresponded to a change in repeatability of single counts from $r = 0.27$ to $r = 0.67$. A scale effect might have been anticipated, since a very low challenge would not allow expression of differences between resistant and susceptible animals. On the other hand, we noted that tick counting was difficult when a large number of ticks was present, which probably explains the negative regression of z on c_2. Setting $c_1 = c_2 = c$ in $z = b_0 + b_1c_1 + b_2c_2 = b_0 + (b_1 - b_2)\,c = 0.4 + 0.08\,c$, indicated that z would increase with tick burden up to the highest c_1 in the sample, c_1 max. $= 2.27$, corresponding to 185 ticks per animal, in which case a correlation of $r = 0.52$ would be expected. For the minimum c_1 observed ($c_1 = 0.71$) the corresponding expected correlation would be reduced to $r = 0.39$.

Table III - Least squares averages of z-transformed correlations for significant effects and standard errors (S.E.). Back-transformed correlations (r) and degrees of freedom (d.f.): S/S = spring/summer, A/W = autumn/winter.

	Z	(S.E.)	r	d.f.
Mean	0.38	0.03	0.36	1641
Seasons of counting				
S/S, S/S	0.42	0.05^a	0.40	666
S/S, A/W	0.24	0.04^b	0.24	738
A/W, A/W	0.41	0.07^a	0.39	237
Regressions				
Lower average burden (transformed count)	0.34	0.01	–	1
Higher average burden (transformed count)	- 0.26	0.01	–	1
Interval between dates of counting (1000 days)	- 0.47	0.02	–	1

[a, b] Means with different subscript differ significantly ($P < 0.05$).

Culling

Income and other distribution problems are studied in Economics through Gini or Lorenz curves (Bronfenbenner, 1972). The present approach to estimating R_i was preferred because it allowed pooling information from small samples for each group.

Sutherst and Utech (1982) pointed out that culling of the less resistant animals would reduce the population of ticks, since "a small proportion of the herd carry the majority of ticks". Culling would be performed most conveniently at the earliest age compatible with development of innate resistance level and because of this, the cumulative distribution of ticks was studied on heifers only. The k parameters are shown in Table IV. Reduction in sum of squares due to fitting separate k values for each group was highly significant ($P < 0.01$). The pooled within-group coefficient of determination was $R^2 = 0.86$. The estimated cumulative distribution of ticks is plotted in Figure 2. Culling the ten percent most infested heifers would eliminate 18 percent of ticks in the HF grade. This proportion would increase for higher Zebu groups up to 26 percent for 1/4 HF: 3/4 G (Table IV). Higher values of k imply distributions more skewed towards the low burden side. Values in Table IV agreed with previous reports indicating a higher proportion of tick resistant animals in Zebus and their crosses than in European cattle (Seifert, 1971, Utech *et al.*, 1978b; Utech and Wharton, 1982).

Culling on tick resistance, to be effective, would have to be repeated on several occasions, because of changes of resistance ranking with time. It is unlikely that high selection intensities could be practised on each occasion, because replacement numbers would then be reduced below acceptable practical limits, as pointed out by Sutherst and Utech (1982), particularly if other traits also were considered for heifer selection. Repeated assessment of resistance also would pose serious practical problems at the farm level. Sutherst and Utech (1982) suggested dividing the herd into high and low resistance sub-units, to be managed on separate pastures, using tick control strategies appropriate to each group. Advantages of this method stem mainly from reduction in use of acaricides on the whole herd. Should the herd be halved, the most

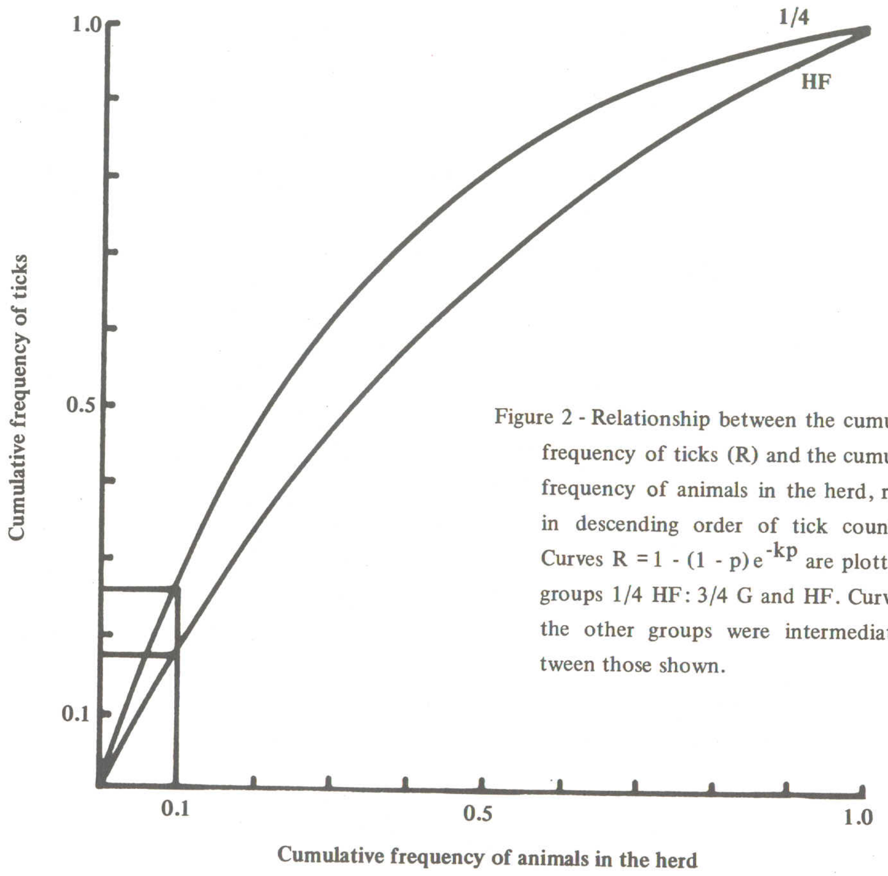

Figure 2 - Relationship between the cumulative frequency of ticks (R) and the cumulative frequency of animals in the herd, ranked in descending order of tick count (p). Curves $R = 1 - (1 - p) e^{-kp}$ are plotted for groups 1/4 HF: 3/4 G and HF. Curves for the other groups were intermediate between those shown.

Table IV -Values of k, asymptotic standard errors (S.E.) in $R = 1 - (1 - p) e^{-kp}$ for each group, and proportion of the tick population expected to be removed by culling $p = 0.10$ (R_{10}) and $p = 0.50$ (R_{50}) most infested heifers.

HF Grade	k	S.E.	R_{10}	R_{50}
1/4	1.973	0.238	0.26	0.81
1/2	1.882	0.099	0.25	0.81
5/8	1.244	0.092	0.21	0.73
3/4	1.303	0.123	0.21	0.74
7/8	1.090	0.095	0.19	0.71
HF	0.881	0.083	0.18	0.68

infested group would carry 81 to 68 percent of the tick population, depending on grade (Table IV).

Heritability

Estimates of variance components for sires, animals and residual are presented in Table V, along with estimated repeatabilities and heritabilities. Repeatabilities were low. Negative estimates of σ_s^2 were found for 5/8 and G sires. However, sire numbers in these two groups were extremely low. Hewetson (1968) reported $h^2 = 0.28$ to 0.42 in AMZ cattle. Phenotypic time trend in young bulls of this breed was consistent with $h^2 = 0.4$ (Hewetson, 1981). Seifert (1971) reported $h^2 = 0.82$ for F_2 - F_3 European: Zebu crossbreds, but reported lack of genetic variation in F_1 animals, which agreed with present results for G sires.

Heritability for HF sires was estimated as $\hat{h}^2 = 0.201$. Wharton *et al.* (1970) reported estimates of $h^2 = 0.39$ to 0.49 for AIS cattle and Seifert (1971) reported estimates not different from zero and $h^2 = 0.48$ in two successive generations of Hereford: Shorthorn crossing. Utech and Wharton (1982) concluded that although tick resistance of European breeds may be improved by selection, very high selection intensities would be required, which would not be commercially feasable. Thus crossbreeding to Zebus would be a faster means of raising tick resistance. The same conclusion is indicated here by the low heritability estimate for HF sires and the marked effect of Zebu breeding reported by Lemos *et al.* (1985).

Table V - Estimates of variance components, repeatability and heritability of transformed tick counts. Standard errors are given within parenthesis.

	Breed of sire		
	HF	5/8[a]	G
σ_s^2	0.0079	- 0.0051	- 0.0163
σ_a^2	0.0400	0.0240	0.0738
σ_w^2	0.1097	0.1213	0.2127
r	0.304	0.165*	0.258*
s.e.r.	0.028	0.051	0.010
h^2	0.201	**	**
s.e.h^2	0.064	–	–

*Setting $\hat{\sigma}_s^2 = 0$; **Negative estimate; [a] 5/8 Holstein Friesian: 3/8 Guzera.

Thus, low estimates of heritability for the progeny of HF and G bulls agreed with previous reports, but not the low estimate for 5/8 bulls. This was probably a sampling effect because Lemos *et al.* (1985) showed that differences between genetic groups in tick burdens were entirely explained by the breed additive difference between HF and G, heterosis effects being non-significant, which indicated that additive variance should be present for this trait in intermediate HF: G grades.

CONCLUSIONS

1. Use of log (2 x count + 1) transformation reduced scale effects, reduced heterogeneity of residual variances within cells of group x counting occasion and greatly reduced skewness and kurtosis.

2. No effects of age within date of counting, days pregnant or days in milk were detected. The absence of age effects for heifers more than 12 months old and for cows in their first or second lactation agreed with previously published results.

3. Correlations between pairs of counts on the same animal made in the same season were r = 0.40 for counts made in spring/summer and r = 0.39 for counts made in autumn/winter, both higher than correlations between counts made in different seasons (r = 0.24). Too high or too low tick burdens reduced correlation which could be expected to be maximum for a burden of 185 ticks per animal. z transformed correlations were reduced by 0.47 for each 1000 days elapsed between both dates of counting, up to 1283 days. Correlations between counts on the same animal as a heifer or as a cow were not affected by animal category when time interval between countings was included in the model.

4. The cumulative distribution of counts indicated that culling of animals on the basis of tick burden would eliminate a more than proportional fraction of the tick population. For example, culling the ten percent most infested heifers would eliminate 18 percent of the tick population in Holstein-Friesians, the latter proportion increasing with Zebu grade, up to 26 percent in 3/4 Guzera heifers. However, because the correlation between counts on the same animal tended to vanish with time, culling of heifers on tick burden does not appear to be warranted.

5. Heritability of transformed count for the progeny of 25 Holstein-Friesian sires was estimated as $h^2 = 0.201$. This low estimate supports the view that selection within European breeds would not be as effective as crossing with zebus to improve tick resistance.

ACKNOWLEDGMENTS

The authors wish to thank Messrs. K.B.W. Utech and R.W. Hewetson for many useful discussions and suggestions. The assistance of Dr. Carmen S. Pereira in statistical analysis is gratefully acknowledged. Mr. R.W. Sutherst kindly reviewed the manuscript.

RESUMO

Foram realizadas 18 contagens de carrapatos em 215 fêmeas provenientes de seis tipos de cruzamento de Holandês vermelho e branco (H): Guzerá (G). Houveram 506 observações em 142 filhas de 25 touros H, 90 observações em 30 filhas de sete touros 5/8 H: 3/8 G e 141 observações em 43 filhas de doze touros G. Foram contadas as fêmeas de carrapatos semi-engorgitadas, medindo entre 4,5 e 8,0 mm de comprimento, no lado direito do animal. As pulverizações com acaricidas foram suspensas, no mínimo 33 e em média 67 dias, antes das contagens. Todos os animais avaliados em cada contagem eram contemporâneos e mantidos juntos nas mesmas pastagens. Alguns animais foram avaliados em mais de uma ocasião. Houveram 357 observações em novilhas e 380 em vacas em lactação. A transformação log (2 x contagem + 1) reduziu a assimetria, a curtose e resultou em variâncias homogêneas dentro das classes de tipo de cruzamento x contagem. Os efeitos de idade dentro de contagem, dias de gestação e dias em lactação não foram significativos ($P > 0.10$). As correlações entre contagens no mesmo animal em ocasiões diferentes foram: r = 0,40 quando ambas as contagens foram feitas em primavera/verão, r = 0,39 quando ambas as contagens foram feitas em outono/inverno, e r = 0,24 quando cada contagem foi feita numa estação diferente. A carga de carrapatos influenciou a correlação entre contagens no mesmo animal. A correlação máxima esperada seria atingida com uma carga de 185 carrapatos por animal, sendo que cargas mais baixas ou mais elevadas resultaram em menor correlação. O aumento do tempo decorrido entre contagens reduziu a sua correlação. A correlação não foi afetada pela categoria do animal (novilha ou vaca), quando o intervalo de tempo entre as contagens foi incluido no modelo. O descarte de 10% das novilhas, pela sua maior infestação, eliminaria 18% da população de carrapatos, nos animais H. Esta última proporção aumentaria com a fração de gens zebu, até 26% nos animais 1/4 H: 3/4 G. A herdabilidade da contagem de carrapatos transformada, foi de $h^2 = 0.201 + 0.064$ para a progênie de touros H. Para as progênies de touros mestiços e G, as estimativas da componente de variância entre pais foram negativas.

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(Received May 17, 1984)