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Comparative performance of six Holstein-Friesian x Guzera crossbred groups in Brazil. 8. Calf mortality

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ABSTRACT

Mortality up to one year of age of 614 artificially reared females of six contemporaneous Holstein-Friesian (HF) x Guzera crossbred groups was analyzed by logistic regression, modeling the probability of death as $\pi = e^y/(1+e^y)$, with the logit y being a linear function of year of birth and age of dam effects, the individual additive breed difference, estimated within F_1 and backcrosses (g_1^I), individual and maternal heterosis (h_1^I and h_1^M) and a term allowing for discrepancy of an *inter se* 5/8 HF cross with the additive-dominance model. The latter improved goodness of fit of the overall model, suggesting the presence of epistatic recombination loss ($P = 0.10$). Significant effects were detected for year ($P = 0.001$) and h_1^I ($P = 0.012$) but not for g_1^I or h_1^M ($P > 0.25$). Model parameters were estimated by maximum likelihood. Derived probabilities of mortality for groups with 1/4, 1/2, 5/8, 3/4, 7/8 and ≥ 31/32 HF fraction were, respectively, 0.092, 0.059, 0.140, 0.065, 0.103 and 0.160 in the best year and 0.225, 0.152, 0.321, 0.167, 0.249 and 0.355 in the worst year. These results confirm literature reports of lower mortality of intermediate crosses, and add support to the advantages of F_1-based systems.

INTRODUCTION

Published figures indicate that, in general, low survival is a major problem for tropical dairy cattle production (e.g. review by Vaccaro, 1990). This author concluded that non-genetic factors had non-predictable and often very marked effects while genetic effects were more consistent. *Bos indicus* and crosses with *B. taurus* had lower losses than purebred *B. taurus*, best survival being recorded for 1/2 to 5/8-European grades. Average crossbred group effects ranged from 12 to 26% mortality in the first year of age. Thus, although losses may be reduced by proper management, this is not the rule, and crossbreeding may be used to achieve higher performance, as is also the case with other traits of economic importance (Madalena *et al.*, 1990b).

Estimates of breed differences and heterosis are needed to design practical crossbreeding programs. Vaccaro (1990) noted that in several studied death losses were lowest in the 1/2 European groups, increasing both above and below this fraction, which suggests important heterosis effects in this trait. However, results from studies attempting to quantify heterosis and breed additive effects for different environments and calf rearing systems are not readily available.

Logistic regression has become a popular tool to study all or none traits such as calf mortality rates

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(e.g. Berger *et al.*, 1992; Azzam *et al.*, 1993) and it is a technique particularly suited to obtain estimates of interpopulational genetic parameters free of confounding environmental effects. The objectives of this research are to present such estimates using data from a more general crossbreeding trial described elsewhere (Madalena, 1989).

MATERIAL AND METHODS

Animals and management

Mortality up to one year of age of 614 female calves was studied. Animals were from six red and white Holstein-Friesian (HF) x Guzera (Gu) crossbred groups, having expected proportions of 1/4, 1/2, 5/8, 3/4, 7/8 and ≥ 31/32 HF genes . There were 91 to 122 animals per group. The halfbreds were F_1 out of Gu dams; the 1/4 HF were first backcrosses to Gu sires. The 3/4, 7/8 and ≥ 31/32 HF were first, second and fifth or higher backcrosses to HF sires. The 5/8 were obtained from *inter se* matings of 5/8 sires and dams. There were 19 HF, 15 Gu and eight 5/8 sires in the present data set. Further information on the genetic background of these animals was given by Lemos *et al.* (1984), who also presented climatic data.

Calves were born between April 1977 and September 1981 at Santa Monica Experimental Station, Municipality of Valencia, State of Rio de Janeiro, where they were reared. Males were disposed of at early ages and could not be included in the study. Females were kept in a nursery building up to two months of age and on pastures thereafter. They were bucket fed colostrum for the first 36 hours and four liters warm whole milk up to four months of age. On pastures they received supplemen- tary minerals, concentrates and roughages in the dry seasons. The health program included navel disinfection at birth and vaccinations against anthrax, foot and mouth disease, penumoenteritis and brucellosis. Gastrointestinal parasites and tick burdens were kept low by chemical control at frequent intervals. Other management details are given by Teodoro *et al.* (1984). Records were kept up to date and included presumed cause of death, as diagnosed by the station veterinarian.

Statistical analyses

Observations were coded as 0 (dead) or 1 (alive). Based on a binomial distribution of mortality, logistic regression was used (Hosmer and Lemeshow, 1989), with parameter estimation by maximum-likelihood (SAS, 1985, CATMOD procedure).

Records were classified by year of birth (four years, with 1980 and 1981 grouped together) and age of dam (three classes: ≤ 4 yr-old; 5 to 7 yr-old and ≥ 8 yr-old).

Logistic and linear regression analyses yielded somewhat different results in preliminary analyses, so the former method was adopted because of its theoretical adequacy for analysis of classification traits (Madalena *et al.*, 1994). The following model was adopted to describe the probability of death (π_{hijk}):

$$\Pi_{hijk} = e^{Y_{hijk}} / (1 + e^{Y_{hijk}})$$

where

$$Y_{hijk} = \mu + M_h + g_1^I q_i + h_1^I z_i + h_1^M w_i + y_j + A_k \qquad (1)$$

and

μ = overall mean,

M_h = effect of the h-th mating type (h = 1 for F_1 or backcrosses, h = 2 for the 5/8 *inter se*),

g_1^I = individual breed additive difference (HF - Gu) within F_1 and backcross groups,

q_i = expected fraction of HF genes in individuals of the i-th crossbred group within F_1 and backcrosses (i = 1, ..., 5; average q = 0.651; q = 1 was assumed for the ≥ 31/32 HF group),

h_1^I = individual heterosis effect within F_1 and backcrosses,

z_i = expected proportion of loci with one gene from each breed in individuals of the i-th crossbred group. z-values were 1/2, 1, 1/2, 1/4, and 0, for grades 1/4, 1/2, 3/4, 7/8 and ≥ 31/32 HF (average z = 0.456).

h_1^M = maternal heterosis effect within F_1 and backcrosses,

w_i = expected proportion of loci with one gene from each breed in dams of the i-th crossbred group. w-values were 1, 0, 1, 1/2, and 0, respectively, for groups 1/4, 1/2, 3/4, 7/8 and ≥ 31/32 HF (average w = 0.521).

Y_j = effect of the j-th year of birth (j = 1, ..., 4),

A_k = effect of the k-th age of dam class (k = 1, ..., 3).

The g_1^I parameter corresponds to Dickerson's (1969) average direct individual HF gene effects, measured as a difference from the Gu breed. The h_1^I and h_1^M parameters measure individual and maternal heterosis effects. They contain dominance and epistatic

Table I - Frequencies of mortality of Holstein-Friesian x Guzera calves up to one year of age.

Holstein-Friesian fraction	Diagnosis: Diarrhoea/ respiratory diseases	Babesiosis/ anaplasmosis	Cachexia	Other[1]	Total Mortality	Number born
	proportion					
1/4	0.049	0.016	0.065	0.041	0.171	122
1/2	0.071	0.010	0.020	0	0.101	99
5/8	0.037	0.055	0.028	0.064	0.184	109
3/4	0.022	0.022	0.033	0.055	0.132	91
7/8	0.030	0.040	0.020	0.040	0.130	100
≥ 31/32	0.064	0.064	0.012	0.064	0.204	93
Total	0.046	0.034	0.031	0.044	0.155	614

[1] Accident, bloat, intoxication, navel disorder, heart deficiency, stillbirth, septicemia, anaphylactic shock.

effects (Dickerson, 1969), which are confounded in the F_1 and backcrosses (Hill, 1982, Koch *et al.*, 1985). In addition, in these crosses the expected proportions of dam's HF genes equal 1 - z_i, so h_1^I is confounded with maternal additive effects (g_1^M), *i.e.*, in fact it estimates $h_1^I - g_1^M$.

Two other genetic models were tested: the additive-dominance model (2) and the crossbred group classification model (3). Under the additive-dominance model 2, g^I, h^I and h^M were fitted ignoring mating type, *i.e.*, dropping the M_h term and including $q_{i'} = 5/8$, $z_{i'} = 30/64$ and $w_{i'} = 1/2$ for the 5/8 group ($i' = 1, ..., 6$). In the classification model 3, discrete crossbred group effects $G_{i'}$ substituted for the g^I, h^I and h^M regressions. Comparative goodness of fit of models was assessed by the likelihood ratio test based on their deviance. The significance of the difference between two models is distributed approximately as χ^2 with d.f. equal to the difference in d.f. between them. In addition, Hosmer and Lemeshow's (1989) $\hat{C}$ statistic was used to assess goodness of fit of models to the data, using ten classes (deciles of risk).

Marginal probabilities of mortality for an effect were calculated setting all other effects equal to their average value.

RESULTS

Frequencies of diagnosed causes of mortality are in Table I. Mortality was due mainly to diarrhoea/ respiratory diseases, plasmosis and cachexia. Analysis of differences between groups in the frequencies of causes of mortality were not attempted because of low subclass numbers.

The maximum likelihood analysis of variance for model 1 is in Table II. Year of birth and h_1^I effects were highly significant and age of dam effects approached significance. A value of $\hat{C} = 9.56$ ($P > 0.25$) indicated an acceptable goodness of fit of this model.

Estimates of model 1 parameters are in Table III. The range in effects of year of birth translates into estimated marginal probabilities of mortality of $\pi_{..1.} = 0.059$ for the best year (1977) and $\pi_{..2.} = 0.154$ for the worst one (1978). Probabilities of mortality were similar for the ≤ 4 and the 5 to 7 yr-old dam age classes ($\pi_{...1} = 0.069$, $\pi_{...2} = 0.066$) and lower than the probability for the ≥ 8 yr-old dams ($\pi_{...3} = 0.118$).

Table II - Maximum likelihood analysis of variance of mortality.

Source	d.f.	Chi-square	Probability
Intercept	1	5.49	0.019
Mating type	1	1.06	0.304
g_1^I	1	0.97	0.325
h_1^I	1	6.29	0.012
h_1^M	1	1.33	0.250
Year	3	16.19	0.001
Age of dam	2	5.20	0.074
Likelihood ratio	54	51.59	0.568

Table III - Estimates of parameters of logistic model 1 for mortality up to one year of age.

Effect	*N*	Estimate	s.e.
μ	614	-1.0181	0.4344
Mating type			
F_1 + backcrosses	505	0.4521	0.4401
5/8 *inter se*	109	-0.4521	0.4401
Regressions			
g^I		-0.7499	0.7617
h^I		-1.4950	0.5962
h^M		-0.4501	0.3910
Year of birth			
1977	157	-0.3396	0.2377
1978	191	0.7195	0.1818
1979	104	-0.2613	0.2583
1980/81	162	-0.1187	0.2148
Age of dam			
≤ 4 yr-old	101	-0.1778	0.2286
5 to 7 yr-old	290	-0.2298	0.1654
≥ 8 yr-old	223	0.4076	0.1974

s.e. = standard error.

As indicated by its negative sign, h_1^I had an important effect on mortality, which was loest for the F_1 and increased as q_i departed from 1/2. Although not significant, g_1^I was negative, *i.e.*, reducing mortality as q_i increased, and at half the magnitude of h_1^I (Table III).

The likelihood ratio test comparing models 1 and 3 (group classification) had $\chi_1^2 = 0.065$ (P > 0.75), indicating similar likelihood of both models. However, the likelihood ratio test comparing models 1 and 2 (additive-dominance) had $\chi_1^2 = 2.706$ (P = 0.10), suggesting that a better fit was obtained by inclusion of the mating type term M_h.

Expected marginal probabilities for the six crossbred groups, averaged over age of dam classes, are shown in Table IV, illustrating the multiplicative effects modeled for the genetic and environmental factors, *i.e.*, differences between crossbred groups increased in the unfavorable years and decreased in the favorable ones. The same applied to the influences of age of dam.

DISCUSSION

Probability statements should be taken with caution because only asymptotically do the observed ratios have a χ^2 distribution, and the numbers of observations were not large. On the other hand, the data set had some reassuring properties for genetic group comparisons (Dickerson, 1993): the crossbred groups were very contemporary (Madalena *et al.*, 1990a), a reasonable sample of unselected sires was used, and the groups were genetically related. The same HF sires were used in all four groups with $q_i \geq 1/2$, the same 1/2 dams generated the 1/4 and 3/4 HF crosses, and these two groups, the 5/8 and the 7/8 all had a common origin (Lemos *et al.*, 1984).

Table IV - Probabilities of mortality (estimated under model 1) for six Holstein-Friesian x Guzera crossbred groups, in the years with the lowest and the highest mortality and in all four years of the study.

Year	Holstein-Friesian fraction					
	1/4	1/2	5/8	3/4	7/8	≤ 31/32
Best (1977)	0.092	0.059	0.140	0.065	0.103	0.160
Worst (1978)	0.225	0.152	0.321	0.167	0.249	0.355
Mean of all four	0.124	0.080	0.187	0.089	0.139	0.211

Preliminary analyses failed to show any consistent seasonal trends, which may perhaps have been blurred by changes in supervisors and calf attendants. Because the data were from a single farm, generalizations perhaps showed not be made, and year of birth effects will not be discussed further, since they were included in models only to avoid confounding and to increase accuracy of the genetic estimates.

Calves born to heifers were reported to have higher perinatal mortality rates than calves born to cows (Berger *et al.*, 1992). Frisch (1973) found a higher mortality of calves from 3-yr-olds than from older dams. Azzam *et al.* (1993) reported decreasing mortality trends for calves from 2-yr-old, 3-yr-old and older dams not experiencing dystocia. Dystocia was not an important factor in the present results. However, the ≤ 4 yr-old class may have included some first and second calvers, thus diminishing any true parity effects (parity information was not available for all dams). The ≥ 8 yr-old dam age class included very old cows (up to 21 yr), unlikely to be present in the above reports, so the higher mortality of calves in this class may not be comparable to much of the literature.

Calf attendants reported difficulties in training 1/4 HF to feed from buckets, which caused more calf losses attributed to cachexia in this group (Table I). Black (1984) indicated that *B. indicus* calves appeared less willing than *B. taurus* to adapt to artificial rearing techniques. Ward *et al.* (1983) reported increased mortality of Sahiwal x Friesian F_1 calves for the same reason, which they circumvented by providing warm milk, shelter and careful training. Warm milk was provided in the present trial, but shelter was not totally adequate during the rainy seasons, and levels of care varied with adjustments in supervision. Thus, the present genetic effects might be different for other calf rearing situations, such as family labor or suckling.

Bucket feeding was chosen in the present trial to attempt to equalize nutrition of crossbred groups. However, it remains to be shown that artificial calf rearing is more economical than suckling for dairy production in developing countries. In fact, calf rearing costs may be higher with artificial rearing than with suckling (Ugarte, 1992); the latter is the predominant practice in Brazil. Paradoxically, most literature results on crossbreeding effects on mortality come from experimental stations practicing artificial rearing. For this type of management, our estimated probabilities of death (Table IV) agreed well with Vaccaro's (1990) summary of 20 reports on young stock losses: 0.154, 0.116, 0.185 and 0.259, for 0 to 1/4, 1/2 to 5/8, 3/4 to 7/8 and ≥ 7/8 European breed fractisons. Trail and Gregory (1982) reported non-significant differences among genetic groups for mortality up to 8 mo. of age of nursed Ayrshire/Simmental x Sahiwal calves.

The h_1^I effects were highly significant and large. The estimated mid-parent and F_1 marginal probabilities of mortality were $\pi = 0.281$ and $\pi = 0.080$, a reduction of 0.201 (confidence limits 0.10 to 0.31) corresponding to the change in the individual heterozygosity from 0 to 1, or in the maternal HF fraction from 1 to 0, since both had a perfect negative correlation. Thorpe *et al.* (1993) reported individual heterosis of 0.05 for survival up to 20 weeks of age in Ayrshire/Friesian x Sahiwal crosses at a mortality level (0.09) lower than the present one. They found smaller, non-significant, direct and maternal effects, favoring the European breeds, whereas maternal heterosis effects also were very small. Under our model and parameter estimates, a difference of 0.05 estimated mortality between F_1 and mid-parent would require 0.015 mortality for the former group, a better performance than the one obtained in the best year (Table IV). However, heterosis estimated by Thorpe *et al.* (1993) resulted mainly from lower survival of the group with the highest zebu gene fraction (0.875), with no clear trend for other groups. Their results, $(h_1^I - g_1^M)/ g_1^I = 0.5$, much lower than our corresponding value of 2.0 (from Table III), suggest that genetic group x environment interactions may exist, other than the multiplicative one accounted for in the present model.

We are not aware of other estimates of breed differences and heterosis effects for tropical dairy calf mortality. For beef calf survival to weaning a literature review by Long (1980) showed average heterosis estimates of 3% (range -2 to 15%), and estimates of 7% for reciprocal effects (range 3 to 13%).

The probability of death for the 5/8 *inter se* group, estimated under the additive-dominance model 2, was $\pi = 0.136$, much lower than the $\pi = 0.187$ estimate under model 1 (Table IV), suggesting the presence of epistatic recombination loss. Coinciding evidence was reported by Bhatnagar *et al.* (1976), Natarajan *et al.* (1980) and Kulkarni *et al.* (1989), who found higher mortality of F_2 than F_1 calves.

The crossbred groups in this study were chosen to represent specific breeding strategies, rather than to estimate genetic parameters (Madalena, 1989). However, regression models, such as model 1, are more informative than classification models, such as model 3, so the former was preferred since both fitted the data equally well, although the h_1^I effects may not strictly be attributed to dominance. However, regardless of the nature of the genetic effects, the present results confirm the trend for lower calf mortality of the genotypes intermediate between *B. indicus* and *B. taurus* found in previous reports, adding support to the advantages of the F_1-based system found for other important economic traits (Madalena, 1993).

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RESUMO

A mortalidade até um ano de idade de 614 bezerras de seis grupos contemporâneos de cruzamentos Holandês (H) x Guzerá, criados com aleitamento artificial, foi analizada através da regressão logística, modelando-se a probabilidade de morte como $\pi = e^y/(1+e^y)$, sendo o "logit" y uma função linear dos efeitos do ano de nascimento e da idade da mãe, da diferença aditiva individual entre as raças (g_1^I) estimada dentro das F_1 e retrocruzamentos, da heterose individual (h_1^I) e materna (h_1^M) e de um termo para a discrepância de um cruzamento 5/8 *inter se* com o modelo aditivo-dominante. Este último termo melhorou o ajuste do modelo, sugerindo perdas epistáticas por recombinação (P = 0,10). Foram detectados efeitos significativos de ano (P = 0,001) e h_1^I (P = 0,012),

mas não de g_1^I nem de g_1^M ($P > 0,25$). Os parâmetros do modelo foram estimados por máxima verossimilhança. As probabilidades de morte derivadas para os gruspos com 1/4, 1/2, 5/8, 3/4, 7/8 e ≥ 31/32 de genes de H, foram, respectivamente, 0,092, 0,059, 0,140, 0,065, 0,103 e 0,160, no melhor ano, e 0,225, 0,152, 0,321, 0,167, 0,249 e 0,355, no pior. Estes resultados confirmam comunicações na literatura de menor mortalidade nos cruzamentos intermediários, apoiando as vantagens dos sistemas baseados nas F_1.

REFERENCES

Azzam, S.M., Kinder, J.E., Nielsen, M.K., Werth, L.A., Gregory, K.E., Cundiff, L.V. and **Koch, R.M.** (1993). Environmental effects on neonatal mortality of beef calves. *J. Anim. Sci. 71*: 282-290.

Berger, P.J., Cubas, A.C., Koehler, K.J. and **Healy, M.H.** (1992). Factors affecting dystocia and early calf mortality in Angus cows and heifers. *J. Anim. Sci. 70*: 1775-1786.

Bhatnagar, D.S., Sharm, R.C. and **Sundaresan, D.** (1976). *Crossbreeding of Cattle for Increased Milk Production*. Pub. N. 143, Nat. Dairy Res. Inst., Karnal, Haryana, pp. 18.

Black, D.H. (1984). Calf rearing in the tropics: behavioural response by *Bos indicus* calves to an artificial rearing system. *Trop. Anim. Hlth. Prod. 16*: 47--48.

Dickerson, G.E. (1969). Experimental approaches in utilizing breed resources. *Anim. Bred. Abstr. 37*: 191-202.

Dickerson, G.E. (1993). *Evaluation of Breed and Crosses of Domestic Animals*. FAO, Rome, Anim. Prod. Health Paper 108, pp. 47.

Frisch, J.E. (1973). Comparative mortality rates of *Bos indicus* and *Bos taurus* cattle in central Queensland. *Aust. J. Exper. Agric. Anim. Husb. 13*: 127-133.

Hill, W.G. (1982). Dominance and epistasis as components of heterosis. *Z. Tierzuchtg. Zuchtgsbiol. 99*: 161-168.

Hosmer, D.W. Jr. and **Lemeshow, S.** (1989). *Applied Logistic Regression*. J. Wiley & Sons, N. York, pp. 307.

Koch, R.M., Dickerson, G.E., Cundiff, L.V. and **Gregory, K.E.** (1985). Heterosis retained in advanced generations of crosses among Angus and Hereford cattle. *J. Anim. Sci. 60*: 1117-1132.

Kulkarni, M.D., Deshpande, P.D., Kale, K.M. and **Narawade, V.S.** (1989). Mortality pattern in Gir and its crosses. *Indian J. Anim. Sci. 59*: 1258-1260.

Lemos, A.M., Teodoro, R.L., Barbosa, R.T., Freitas, A.F.F. and **Madalena, F.E.** (1984). Comparative performance of six Holstein-Friesian x Guzera grades in Brazil. 1. Gestation length and birth weight. *Anim. Prod. 38*: 157-164.

Long, C.R. (1980). Crossbreeding for beef production: Experimental results. *J. Anim. Sci. 51*: 1197-1223.

Madalena, F.E. (1989). Cattle breed resource utilization for dairy production in Brazil. In: *Utilization of Animal Genetic Resources in Latin America* (Duarte, F.A.M.; Madalena, E.F. and Lôbo, R.B., eds.). *Proceedings of an International Symposium*, 4-9 September 1989, Ribeirão Preto, SP, Brazil. *Rev. Brasil. Genet. 12* (Suppl.): 183-220.

Madalena, F.E. (1993). A simple scheme to utilize heterosis in tropical dairy cattle. *Wld. Anim. Rev.* (FAO) *74*: 17-25.

Madalena, F.E., Lemos, A.M., Teodoro, R.L., Barbosa, R.T. and **Monteiro, J.B.N.** (1990a). Dairy production and reproduction in Holstein-Friesian and Guzera crosses. *J. Dairy Sci. 73*: 1872-1886.

Madalena, F.E., Teodoro, R.L., Lemos, A.M., Monteiro, J.B.N. and **Barbosa, R.T.** (1990b). Evaluation of strategies for crossbreeding of dairy cattle Brazil. *J. Dairy Sci. 73*: 1887-1901.

Madalena, F.E., Teodoro, R.L. and **Lemos, A.M.** (1994). Uso da regressão logística para estimar heterose em características de classificação. *Rev. Brasil. Genet. 17* (Suppl.): 355.

Natarajan, C., Shanker, H. and **Singh, R.** (1980). Note on a three-year study on the pattern of mortality in crossbred cattle in three livestock farms. *Indian J. Anim. Sci. 50*: 996-998.

SAS (1985). *SAS User's Guide: Statistics*. SAS Inst. Inc., Cary, NC.

Teodoro, R.L., Lemos, A.M., Barbosa, R.T. and **Madalena, F.E.** (1984). Comparative performance of six Holstein-Friesian x Guzera grades in Brazil. 2. Traits related to the onset of the sexual function. *Anim. Prod. 38*: 157-164.

Thorpe, W., Kang'ethe, P., Rege, J.E.O., Mosi, R.O., Mwandotto, B.A.J. and **Njuguna, P.** (1993). Crossbreeding Ayrshire, Friesian and Sahiwal cattle for milk yield and preweaning traits of progeny in the semiarid tropics of Kenya. *J. Dairy Sci. 76*: 2001-2012.

Trail, J.C.M. and **Gregory, K.E.** (1982). Production characters of the Sahiwal and Ayrshire breeds and their crosses in Kenya. *Trop. Anim. Hlth. Prod. 14*: 45-57.

Ugarte, J. (1992). Crianza de terneros. In: *Avances en la Produccion de Leche y Carne en el Tropico Americano* (Fernandez-Baca, S., ed.). FAO, Santiago de Chile, pp. 261-306.

Vaccaro, L.P. (1990). Survival of European dairy breeds and their crosses with Zebus in the Tropics. *Anim. Breed. Abstr. 58*: 475-494.

Ward, J.D.B., Bremner, K.J. and **Kilgour, R.** (1983). Behaviour factors influencing the rearing of Sahiwal cross calves. *Proc. N. Zeal. Soc. Anim. Prod. 43*: 171-173.

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