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COMPARATIVE PERFORMANCE OF SIX HOLSTEIN-FRIESIAN × GUZERA GRADES IN BRAZIL

1. GESTATION LENGTH AND BIRTH WEIGHT

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ABSTRACT

Gestation length and birth weight of 939 calves born at Santa Mônica Experimental Station, Valença, State of Rio de Janeiro, were studied. The calves were of six red and white Holstein-Friesian (HF) × Guzera (G) grades: 1/4, 1/2, 5/8, 3/4, 7/8 and ≥ 31/32.

As the grade × sex interaction for birth weight was significant, data for each sex were analysed separately. A model, including the effects of grade, year-season of birth, grade × year season interaction and age of dam as a covariate, resulted in the following least-square means for the six grades in the above order (± s.e.): gestation length for cows carrying male calves, 290·0 (± 0·9), 281·2 (± 0·9), 285·3 (± 0·8), 278·8 (± 0·9), 280·5 (± 0·9) and 279·3 (± 0·9) days; gestation length for female calves, 287·5 (± 0·9), 280·1 (± 1·0), 285·3 (± 0·9), 274·5 (± 1·1), 279·2 (± 0·9) and 276·4 (± 1·0) days; birth weight for males, 34·6 (± 0·7), 28·6 (± 0·8), 34·2 (± 0·7), 32·4 (± 0·7), 35·0 (± 0·7) and 34·7 (± 0·7) kg; birth weight for females, 29·9 (± 0·6), 29·5 (± 0·7), 33·4 (± 0·6), 31·9 (± 0·7), 33·6 (± 0·6) and 32·6 (± 0·6) kg.

Direct (g^I) and maternal (g^M) breed additive effects (HF − G), and direct (h^I) and maternal heterosis (h^M) were estimated. The estimates of g^I, g^M, h^I and h^M were respectively, for gestation length for male calves: −21·5 (± 1·9), 10·6 (± 2·1), 1·5 (± 1·8) and −1·6 (± 1·1) days; for gestation length, for female calves: −21·9 (± 2·1), 14·6 (± 2·5), 5·7 (± 2·1) and −1·5 (± 1·2) days; for birth weight of male calves: −3·5 (± 1·5), 7·1 (± 1·8), −0·6 (± 1·5) and 1·0 (± 0·9) kg; and for birth weight of female calves: 4·7 (± 1·4), 4·1 (± 1·6), 2·8 (± 1·3) and 2·0 (± 0·8) kg. The difference in birth weight between males and females was 4·7 (± 0·9) for G-sired calves and 0·8 (± 0·4) for HF-sired calves.

INTRODUCTION

CROSSBREEDING of European × zebu breeds (mainly Holstein-Friesian and Gir or Guzera) is a common practice in the main dairy production areas of tropical Brazil, as farmers try to maintain intermediate grades because they are better adapted to the prevailing physical and socio-economic environment. However, because of lack of information on the performance of cattle of varying European grade and heterozygosity, it is difficult to define breeding strategies appropriate to the diverse production systems existing in the region. A trial was therefore set up to measure the performance of contemporary animals of six Holstein-Friesian × Guzera grades in cooperator farms of varying levels of management. The background and rationale for this trial were described by Madalena (1981).

In this paper, results on birth weight and gestation length are presented, together with a description of the genetic background of the cattle involved.

MATERIAL AND METHODS

Animals

Data on 939 calves of six red and white Holstein-Friesian (HF) × Guzera (G) grades

† Project IICA/EMBRAPA.

were studied. Throughout this paper, grade means the expected fraction of HF genes, the implicit complement adding up to 1 coming from the G breed. The six grades were: 1/4, 1/2, 5/8, 3/4, 7/8 and ≥ 31/32 or HF. Calves of these six grades were contemporary, born between June 1977 and May 1980. The halfbreds were F_1 out of G dams and HF sires. The 1/4 and 3/4 were first backcrosses of F_1 dams to, respectively, G and HF sires. The 7/8 were second backcrosses to HF sires, and the 5/8 were obtained by mating 5/8 dams to 5/8 sires. Actual and effective numbers (Robertson, 1953) of sires and dams are shown in Table 1. The HF dams were registered (≥ 15/16 HF) and bought from 11 commercial farms. The G dams were obtained from four farms. The 1/2, 3/4 and 5/8 grade dams resulted from a previous project in which HF sires were initially crossed with G type dams to obtain 1/2; these were then backcrossed to HF sires to obtain 3/4, and 1/2 × 3/4 reciprocal crosses were made to obtain the 5/8. Numbers of sires and dams at each of these three ancestral generations are shown in Table 2. A total of 16 HF sires were used in the previous project.

The calves in the present study were sired by artificial insemination bulls. HF and G sires were from local commercial companies, and 5/8 sires had the same origin as described above for 5/8 dams. HF calves were sired by 14 bulls, of which 10 also sired the calves of 1/2, 3/4 and 7/8 grades. Nine of the 14 HF bulls were Brazilian and five were imported as young bulls from Canada or the USA.

TABLE 1
Holstein-Friesian (HF) grades, and numbers of sires and dams of groups studied

HF grade of			No. sires		Actual
Calves	Sires	Dams	Actual	Effective	no. dams
HF	HF	HF	14	10·6	81
7/8	HF	3/4	10	9·1	98
3/4	HF	1/2†	10	9·8	130
5/8	5/8	5/8	8	3·2	81
1/2	HF	G	10	10·0	106
1/4	G	1/2†	10	9·6	138

† Same herd.

Climate and management

The calves were born at Santa Mônica Experimental Station, Municipality of Valença, State of Rio de Janeiro. The farm is located in a hilly region, altitude ranging from 200 to 400 m. The climate corresponds to Cwa of Koeppen's classification (mild dry winter, hot summer) (Carmo and Nascimento, 1961), the dry season extending from April to

TABLE 2
Holstein-Friesian (HF) grades, and numbers of sires and dams represented in three ancestor generations of crossbred calves

		HF grade of			No. sires		Actual
Ancestors of	Generation	Individual	Sires	Dams	Actual	Effective	no. dams
5/8 grade calves	1†	1/2	HF	G	11	10·0	55
	2	3/4	HF	1/2	8	4·7	35
	3	5/8‡	1/2	3/4	5	2·8	45
	3	5/8‡	3/4	1/2	7	3·1	30
7/8 grade calves	1†	1/2	HF	G	9	8·3	58
	2	3/4‡	HF	1/2	13	5·0	98
3/4 grade calves	1†	1/2‡	HF	G	13	7·7	105
1/4 grade calves	1†	1/2‡	HF	G	14	8·8	109

† Minimum numbers of sires and dams for this generation, because of pedigree records missing for some animals.
‡ Dams of calves in the present study.

TABLE 3

Mean monthly temperatures and monthly rainfall, for the period July 1976 to June 1980

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Mean	22·9	24·1	23·5	20·6	19·6	17·9	17·5	18·8	19·8	21·7	21·0	22·7	22·5
Maximum	28·7	30·1	28·4	26·7	26·3	24·3	24·8	26·2	24·9	27·8	26·9	28·2	26·9
Minimum	19·3	19·3	20·0	16·9	14·7	14·6	14·0	13·9	15·2	16·8	16·9	18·7	16·7
Rainfall (mm)	242	134	133	61	41	25	24	52	92	75	170	232	1280

September. Climatic data for 1976 to 1980 are shown in Table 3.

Cows were kept on native pastures, in which the main species was molasses grass (*Melinis minutiflora* Palm. de Beauv.). Lactating cows were supplemented with chopped elephant grass (*Pennisetum purpureum* Schum.) during the rainy season and elephant grass silage plus 2 to 4 kg of sugar cane molasses during the dry season. In addition, they received approximately 1 kg of commercial concentrate mixture (160 g crude protein per kg) per 3 kg of milk produced. Dry cows were supplemented with elephant grass silage plus molasses during the dry season. A mineral mix was included at 20 g/kg in the concentrate for milking cows and was also available in the paddocks to all cows. The mineral mix was composed of (g/kg): 800 bone-meal, 198·1 salt, 1·2 $CuSO_4$, 0·1 $CoSO_4$, 0·5 ZnO and 0·1 KI.

Ticks (*Boophilus microplus* Can.) and Torsalo grubs (*Dermatobia hominis* L.) were important parasites. An outbreak of brucellosis affected the herd between 1977 and 1979.

Approximately 1 month before calving, cows were brought to a small paddock for closer observation. Calves were weighed and identified within 16 h of birth.

Statistical analyses

Data were analysed by least-squares techniques using the computer program of Harvey (1972), with all effects considered to be fixed. Records were classified into dry (April to September) and rainy (October to March) seasons of calving. In preliminary analyses, sires within year-seasons had no significant effects on birth weight or gestation length ($P > 0{\cdot}05$) and were not considered thereafter. Since the preliminary analyses indicated the presence of grade × sex interaction for birth weight, data for both sexes were analysed separately. The following models were fitted:

$$Y_{ijk} = b_0 + G_i + YS_j + GYS_{ij} + b_1 a_{ijk} + b_2 a^2_{ijk} + e_{ijk} \quad \text{(model 1)}$$

$$Y_{ijk} = b_0 + G_i + YS_j + b_1 a_{ijk} + b_2 a^2_{ijk} + e_{ijk} \quad \text{(model 2)}$$

where Y_{ijk} represents the birth weight or gestation length of the kth calf of the jth year-season ($j = 1, \ldots, 6$) and the ith grade ($i = 1, \ldots, 6$) and a_{ijk} represents the age of its dam. G_i represents the effect of the ith grade, YS_j the effect of the jth year-season and GYS_{ij} the interaction of these two factors.

Estimates of direct (g^I) and maternal (g^M) breed additive effects and of direct (h^I) and maternal (h^M) heterosis were obtained according to the following model:

$$Y_{ijk} = b_0 + g^I q^I_i + g^M q^M_i + h^I z^I_i + h^M z^M_i + YS_j + b_1 a_{ijk} + b_2 a^2_{ijk} + e_{ijk} \quad \text{(model 3)}$$

where Y, YS and a have the same meaning as above, q^I_i and q^M_i represent, respectively, the expected HF gene frequency of an individual and its dam, and z^I and z^M represent, respectively the expected heterozygosity of the individual and its dam. Assuming independent loci, $z = u(1 - v)$

$+ v(1 - u)$, where u and v represent, respectively, the HF grade of each progenitor. Model 3 is the same as model 2 except that G effects of the latter are substituted by the four genetic parameters, i.e. $G_i = g^I q_i^I + g^M q_i^M + h^I z_i^I + h^M z_i^M$. Estimates of these four genetic parameters could not be obtained from a straight multiple-regression analysis (Robison, McDaniel and Rincón, 1981) because z^I_i was confounded with q^M_i (i.e. $z^I_i = 1 - q^M_i$) for all grades except 5/8. Estimates were then obtained in two steps. First, the following model was fitted to the data subset excluding the 5/8:

$$Y_{ijk} = b_0 + g^I q_i^I + (g^M - h^I)\, q_i^M + h^M z_i^M + YS_j + b_1 a_{ijk} + b_2 a_{ijk} + e_{ijk} \qquad \text{(model 4)}$$

Secondly, g^M and h^I were separated, incorporating the information from the 5/8, the mean of which can be written in terms of model 3 as:

$$\bar{Y}_{5/8} = b_o + (5/8)g^I + (5/8)g^M + (30/64)h^I + (1/2)h^M + \bar{e}.$$

Using $\hat{g}^M - \hat{h}^I = \widehat{(g^M - h^I)}$, it was possible to solve for $\hat{g}^M$ and $\hat{h}^I$ as functions of the estimates ($\hat{}$) yielded by model 4 and the observed mean of the 5/8. Thus, $70\,\hat{g}^M = 64\,(\bar{Y}_{5/8} - \hat{b}_0) - 40\,\hat{g}^I - 32\,\hat{h}^M + 30\,\widehat{(g^M - h^I)}$ and $\hat{h}^I = \hat{g}^M - \widehat{(g^M - h^I)}$. The standard errors of $\hat{g}^I$ and $\hat{h}^M$ were obtained directly from model 4, whereas the standard errors of $\hat{g}^M$ and $\hat{h}^I$ were worked out from the variances and covariances of the relevant estimates of model 4 and $\bar{Y}_{5/8}$.

Goodness of fit of model 3 was assessed by F-tests of the extra m.s. due to fitting model 2 after model 3 against the model 2 residual m.s. To this effect, residual sums of squares for model 3 were calculated as $\Sigma_{ijk}\ (Y_{ijk} - \hat{Y}_{ijk})^2$, which was subtracted from the total sums of squares to obtain model 3 sums of squares. Contrasts were tested by the method of Scheffé (1959).

RESULTS

Analyses of variance for model 1 are presented in Table 4, the effect of each term being that obtained after all other terms in the model have been fitted. Grade effects were significant for both traits and sexes ($P < 0{\cdot}001$), and so were year-season effects ($P < 0{\cdot}05$ to $0{\cdot}001$). The grade × year-season interaction was significant for the gestation length of females and for the birth weight of both sexes. Least-squares means for the six grades are shown in Table 5. Gestations were longer for 1/4 and 5/8 grade calves of both sexes. Birth weights of males were similar for all grades except half breds, which were lighter. Females of 1/4 and 1/2 grades were lighter than females of other grades.

Statistics of the analyses of variance for models 1, 2 and 3 are presented in Table 6.

TABLE 4
Mean squares for birth weight and gestation length

Source	d.f.	Birth weight (kg^2)		Gestation length ($days^2$)	
		Males	Females	Males	Females
Grade	5	318***	181***	1272***	1685***
Year-season	5	76*	99***	110*	234***
Grade × year-season	25	54**	60***	52	88*
Age of dam					
linear	1	206***	89*	6	267*
quadratic	1	159*	60	1	182
Residual					
males	435	29	—	45	—
females	428	—	23	—	52

TABLE 5

Least-squares means with standard errors for birth weights and gestation lengths of calves of six Holstein-Friesian (HF) × Guzera grades

	No.		Birth weight (kg)				Gestation length (days)			
			Males		Females		Males		Females	
HF grade	Males	Females	Mean	s.e.	Mean	s.e.	Mean	s.e.	Mean	s.e.
1/4	81	97	34·6[a]†	0·7	29·9[bc]	0·6	290·0[a]	0·9	287·5[a]	0·9
1/2	72	71	28·6[b]	0·8	29·5[c]	0·7	281·2[c]	0·9	280·1[b]	1·0
5/8	73	79	34·2[a]	0·7	33·4[a]	0·6	285·3[b]	0·8	285·3[a]	0·9
3/4	94	68	32·4[a]	0·7	31·9[abc]	0·7	278·8[c]	0·9	274·5[c]	1·1
7/8	87	89	35·0[a]	0·7	33·6[a]	0·6	280·5[c]	0·9	279·2[b]	0·9
HF	66	62	34·7[a]	0·7	32·6[ab]	0·6	279·3[c]	0·9	276·4[bc]	1·0
Mean or total	473	466	33·2	0·3	31·8	0·2	282·5	0·3	280·5	0·4

† a, b, c: grade means with different superscripts differ significantly ($P < 0{\cdot}05$).

TABLE 6

Statistics for models 1, 2 and 3

	Birth weight		Gestation length	
	Males	Females	Males	Females
Model 1				
Total reduction				
m.s.	94·30	62·88	270·14	382·23
d.f.	37	37	37	37
Residual				
m.s.	29·12	22·81	45·09	51·88
d.f.	435	428	435	428
R^2	0·22	0·19	0·34	0·39
Model 2				
Total reduction				
m.s.	179·08	67·83	725·54	995·99
d.f.	12	12	12	12
Residual				
m.s.	30·45	24·89	45·45	53·85
d.f.	460	453	460	453
R^2	0·13	0·07	0·29	0·33
Model 3				
Total reduction				
m.s.	185·68	46·02	757·78	976·24
d.f.	11	11	11	11
Residual				
m.s.	30·62	25·51	46·15	56·40
d.f.	461	454	461	454
R^2	0·13	0·04	0·28	0·30
Extra variation due to fitting model 2 after model 3				
m.s.	106·41	307·62	370·92	1213·23
d.f.	1	1	1	1
F	3·49NS	12·36**	8·16**	22·53**

Model 2 did not fit the data as well as model 1, with the exception of gestation length of males, due to the grade × year-season interactions. The extra variation due to fitting model 2 after model 3 was significant for all traits except birth weight of males ($P < 0.05$).

Direct additive effects (HF − G) on birth weight were negative in males and positive in females (Table 7). Maternal additive effects were positive in both sexes, but larger in males than in females. Estimates of direct and maternal heterosis for birth weight were larger than two standard errors for females but not for males.

Direct additive effects (HF − G) reduced gestation length of calves of both sexes by approximately 21 days, while maternal additive effects increased gestation length, by 11·9 and 15·8 days, respectively, for male and female calves (Table 7). Both direct and maternal heterosis effects on gestation length were small and of the order of their standard errors, except for direct heterosis on females (Table 7).

DISCUSSION

Since grade × year-season interactions were generally present, reported grade effects are only valid as averages over the range of year-seasons studied, the same applying to estimates of direct and maternal breed additive and heterotic effects. Interaction between heterosis and environment were considered the rule rather than the exception by Barlow (1981).

If the four genetic parameters included in model 3 had accounted for all the variation between grades, models 2 and 3 should have fitted the data equally well, which was not the case. The better fit of model 2 (Table 6) indicates that other genetic effects, not included in model 3, were operating in these traits, with the possible exception of birth weight of males. Sheridan (1981) suggested epistasis to be an important cause of heterosis in domestic animals.

Present results are in agreement with previous reports indicating longer gestation lengths for zebu than for European breeds, and intermediate lengths for their crosses (Andersen and Plum, 1965; Wijeratne, 1970; Tomar and Arora, 1972; Barlow and O'Neill, 1978; Melucci, Miquel and Molinuevo, 1978; Gregory, Smith, Cundiff, Koch and Laster, 1979; Reynolds, De Rouen, Moin and Koonce, 1980). HF calves had a gestation length of 277·9 (s.e. 0·7) days (mean of both sexes), which agrees well with the results of five reports for the same breed in Brazil (reviewed by Pereira and Miranda, 1978) in which mean gestation length ranged between 275 and 277 days, averaging 276·3 days. These values are smaller than the 279·5 days reported by Andersen and Plum (1965) for temperate countries.

The mean gestation length for cows carrying purebred G calves in two reports reviewed by Pereira and Miranda (1978) was

TABLE 7

Estimates of direct (g^I) and maternal (g^M) breed additive differences (HF minus G) and individual (h^I) and maternal (h^M) heterosis effects, with standard errors

	Birth weight (kg)				Gestation length (days)			
	Males		Females		Males		Females	
Estimate	Mean	s.e.	Mean	s.e.	Mean	s.e.	Mean	s.e.
g^I	−3.5	1.5	4.7	1.4	−21·5	1·9	−21·9	2·1
g^M	7·9	1·9	4·5	1·7	11·9	2·2	15·8	2·6
h^I	0·2	1·4	3·2	1·4	2·8	1·9	6·9	2·2
h^M	1·0	0·9	2·0	0·8	−1·6	1·1	−1·5	1·2

287·2 days. The difference between the means for HF − G from previous Brazilian studies, i.e. 276·3 − 287·2 = −10·9 days, is similar to the predicted difference of −7·9 days obtained by adding g^I and g^M estimates, averaged over sexes (Table 7). We are not aware of other estimates of direct and maternal breed effects on gestation length for crosses of European and zebu breeds, but estimates of g^I could be obtained by doubling breed of sire differences in experiments where two sire breeds were crossed to the same dam breeds. Thus, g^I values of −21 and −18 days were obtained for the difference HF − Brahman, from the results of Barlow and O'Neill (1978) and Melucci *et al.* (1978), respectively, and $g^I = -17$ days for HF − Hariana from Tomar and Arora (1972). These values are similar to the estimates of $g^I = -21{\cdot}7$ (s.e. 1·4) obtained by averaging the g^I estimates of Table 7 for both sexes.

The estimates of g^M (Table 7) were positive, i.e. an increase of one unit in the HF grade of the dam prolonged gestation length by approximately 12 days in males and 16 days in females. With the exception of the h^I estimate for females, heterotic effects on gestation length were small, as would be expected from the literature (Long, 1980; Reynolds *et al.*, 1980).

Birth weights of HF male and female calves were, respectively, 34·7 (s.e. 0·7) and 32·6 (s.e. 0·6) kg, which were lower than the corresponding averages of four Brazilian reports on the same breed, 37·7 and 35·0 kg (Teodoro, 1978). Average birth weights for temperate countries are much higher, 44·0 and 41·0 kg respectively for males and females (Andersen and Plum, 1965).

Previous reports have indicated an increase in birth weight for increased HF grade in crosses with zebu breeds (Branton, McDowell and Brown, 1966; Naidu and Desai, 1966; Taneja and Bhat, 1972). Higher European grades increased birth weights also in Brown Swiss × Sahiwal or Red Sindhi crosses (Rao, Nagarcenkar and Sharma, 1975).

The estimates of g^I and g^M for birth weight were different for both sexes (Table 7). Seifert and Kennedy (1966), Barlow and O'Neill (1978) and Bailey and Moore (1980) reported that the difference between sexes in birth weight was larger for progeny of *Bos indicus* sires than for progeny of *B. taurus* sires, which agrees with the results of Ellis, Cartwright and Kruse (1965) and Turner and McDonald (1969). The difference between birth weights of males and females was 4·7 (s.e. 0·9) kg (Table 5) for the 1/4 grade calves (G sires) and 0·8 (s.e. 0·4) kg for the other five grades (HF sires). It would then appear that a larger sexual dimorphism is displayed by zebu-sired calves, although a European or crossbred dam may be necessary for the expression of this effect, since the sex difference in birth weights of purebred zebus is not larger than that of purebred European calves. Mean birth weights of male and female calves in nine studies on Brazilian zebu breeds (Teodoro, 1978) were, respectively, 27·4 and 25·2 kg. As pointed out by Cartwright (1973), the zebu cow restricts foetal growth, not allowing the expression of its growth potential.

Reported estimates of h^I for birth weight in European × zebu crosses have ranged between 0·04 and 0·15 of mid-parent value (Ellis *et al.*, 1965; Reynolds *et al.*, 1980; Trail, Gregory, Marples and Kakonge, 1982). h^I values of Table 7, expressed as a proportion of estimated mid-parent value, were 0·005 for males and 0·105 for females. Thus, although on average present h^I estimates are within the range of published values, heterotic effects were smaller for males than for females.

The differences between sexes in the estimates of genetic parameters account for the grade × sex interaction found in the preliminary analyses of variance of birth weight and gestation length.

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REFERENCES

ANDERSEN, H. and PLUM, M. 1965. Gestation length and birth weight in cattle and buffaloes: a review. *J. Dairy Sci.* **48:** 1224-1235.

BAILEY, C. M. and MOORE, J. D. 1980. Reproductive performance and birth characters of divergent breeds and crosses of beef cattle. *J. Anim. Sci.* **50:** 645-652.

BARLOW, R. 1981. Experimental evidence for interaction between heterosis and environment in animals. *Anim. Breed. Abstr.* **49:** 715-737.

BARLOW, R. and O'NEILL, G. H. 1978. Performance of Hereford and crossbred Hereford cattle in the subtropics of New South Wales: Growth of first cross calves to weaning. *Aust. J. agric. Res.* **29:** 1313-1324.

BRANTON, C., MCDOWELL, R. E. and BROWN, M. A. 1966. Zebu-European crossbreeding as a basis of dairy cattle improvement in the U.S.A. *Sth. Coop. Ser. Bull. La agric. Exp. Stn, No. 114.*

CARMO, J. DO and NASCIMENTO, C. B. 1961. [Study on the performance of the Holstein-Friesian breed, black and white variety, at the Expt. Breeding farm "Santa Mônica", Juparanã, State of Rio de Janeiro.] *Publ. Inst. Zootec., Min. Agric., Rio de J., No. 39.*

CARTWRIGHT, T. C. 1973. Comparison of F_1 cows with purebreds and other crosses. In *Crossbreeding Beef Cattle. Series 2* (ed. M. Koger, T. J. Cunha and A. C. Warnick), pp. 49-63. University of Florida Press, Gainesville.

ELLIS, G. F., JR., CARTWRIGHT, T. C. and KRUSE, W. E. 1965. Heterosis for birth weight in Brahman-Hereford crosses. *J. Anim. Sci.* **24:** 93-96.

GREGORY, K. E., SMITH, G. M., CUNDIFF, L. V., KOCH, R. M. and LASTER, D. B. 1979. Characterization of biological types of cattle — Cycle III : I. Birth and weaning traits. *J. Anim. Sci.* **48:** 271-279.

HARVEY, W. R. 1972. User's guide for least squares and maximum likelihood general purpose program. Ohio State University, Columbus (Mimeograph).

LONG, C. R. 1980. Crossbreeding for beef production: experimental results. *J. Anim. Sci.* **51:** 1197-1223.

MADALENA, F. E. 1981. Crossbreeding strategies for dairy cattle in Brazil. *Wld Anim. Rev.* **38:** 23-30.

MELUCCI, L., MIQUEL, M. C. and MOLINUEVO, H. A. 1978. [Calving and weaning rates and dystocia of F_1 dams.] *Proc. Semin. Heterosis Beef Cattle Prod. Systems, Balcarce.*

NAIDU, K. N. and DESAI, R. N. 1966. Some factors affecting birth weight in crossbred generations of Holstein-Friesian × Sahiwal cattle. *Indian J. vet. Sci.* **36:** 135-139.

PEREIRA, J. C. C. and MIRANDA, J. J. F. 1978. [*Cattle Reproductive Efficiency.*] Escola de Veterinária, Universidade Federal de Minas Gerais, Belo Horizonte (Mimeograph).

RAO, M. K., NAGARCENKAR, R. and SHARMA, K. N. S. 1975. Evaluation of performance of Brown Swiss × zebu crosses for early traits. *Indian J. Anim. Sci.* **45:** 514-520.

REYNOLDS, W. L., DE ROUEN, T. M., MOIN, S. and KOONCE, K. L. 1980. Factors influencing gestation length, birth weight and calf survival of Angus, Zebu and Zebu cross beef cattle. *J. Anim. Sci.* **51:** 860-867.

ROBERTSON, A. 1953. A numerical description of breed structure. *J. agric. Sci., Camb.* **43:** 334-336.

ROBISON, O. W., MCDANIEL, B. T. and RINCÓN, E. J. 1981. Estimation of direct and maternal additive and heterotic effects from crossbreeding experiments in animals. *J. Anim. Sci.* **52:** 44-50.

SCHEFFÉ, H. 1959. *The Analysis of Variance.* Wiley, New York.

SEIFERT, G. W. and KENNEDY, J. F. 1966. Some observations on the birth weight of beef cattle. *Proc. Aust. Soc. Anim. Prod.* **6:** 257-259.

SHERIDAN, A. K. 1981. Crossbreeding and heterosis. *Anim. Breed. Abstr.* **49:** 131-144.

TANEJA, V. K. and BHAT, P. N. 1972. Genetic and non-genetic factors affecting body weights in Sahiwal × Friesian crosses. *Anim. Prod.* **14:** 295-298.

TEODORO, R. L. 1978. [Environmental and genetic effects on the birth weight of calves of the Caracu breeds.] *M.Sc. Thesis, Escola Vet., Univ. Federal de Minas Gerais, Belo Horizonte.*

TOMAR, S. S. and ARORA, K. L. 1972. The influence of different breeds of exotic sires on the gestation length of Hariana cows. *Indian vet. J.* **49:** 572-577.

TRAIL, J. C. M., GREGORY, K. E., MARPLES, H. J. S. and KAKONGE, J. 1982. Heterosis, additive maternal and additive direct effects of the Red Poll and Boran breeds of cattle. *J. Anim. Sci.* **54:** 517-523.

TURNER, J. W. and MCDONALD, R. P. 1969. Mating-type comparisons among crossbred beef cattle for preweaning traits. *J. Anim. Sci.* **29:** 389-397.

WIJERATNE, W. V. S. 1970. Crossbreeding Sinhala cattle with Jersey and Friesian in Ceylon. *Anim. Prod.* **12:** 473-483.

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