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Distribution and production characteristics of Friesian crossbred cattle in Malaysia

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Key words: dairy cattle, crossbreeding, Friesian grades

Abstrak

Prestasi lembu tenusu tempatan (LID), Friesian dan beberapa gred kacukan telah dikaji dengan menggunakan model linear berdasarkan tahun, musim dan umur beranak. Sejumlah 19.4% daripada kacukan F_1 mempunyai laktasi kurang daripada 120 hari dan 57.7% daripada ternakan ini menghasilkan susu melebihi 1 000 kg manakala 22.0% menghasilkan susu melebihi 2 000 kg. Umur beranak tiada kaitan dengan tempoh laktasi. Kesan tahun dan musim (berdasarkan jumlah hujan) dalam satu tahun ketara untuk semua ciri kecuali tempoh laktasi. Kesan umur beranak pertama hanya ketara bagi hari terbuka. Hasil purata susu laktasi pertama meningkat daripada 685 kg bagi LID menjadi 1 309 kg bagi kacukan F_1. Kacukan-kacukan 62.5, 75 dan 87.5% gred Friesian masing-masing menghasilkan 1 513, 1 362 dan 1 507 kg susu pada laktasi yang sama. Pembaikan yang sama didapati bagi umur beranak pertama tetapi pembaikan tidak tetap bagi julat beranak, hari terbuka dan tempoh pembiakan. Prestasi keseluruhan yang dihuraikan sebagai hasil susu sehari bagi sepanjang hayat tidak berbeza secara ketara di antara kacukan-kacukan yang mempunyai 50% atau lebih keturunan Friesian kecuali yang dihasilkan daripada kacukan inter se. Keturunan Friesian yang memberi penghasilan yang tertinggi dianggarkan pada 60% darah Friesian. Peningkatan standard pengurusan masa kini akan membolehkan peratus ini ditinggikan lagi bagi mencapai pengeluaran yang lebih tinggi.

Abstract

The performance of the Local Indian Dairy (LID) cattle, Friesian and their various grades of crossbreds were studied using generalized linear models with year, season and calving age as effects. A total of 19.4% of the F_1 crossbreds had lactations less than 120 days and 57.7% of this genotype produced more than 1 000 kg of milk and 22.0% produced more than 2 000 kg of milk. Calving age was not correlated with lactation length. Year and season (based on rainfall levels)-within-year effects were highly significant in the model for all traits except days open. First calving age effect was significant only for days open. Average first lactation milk yield increased from 685 kg among the LID to 1 309 kg among the F_1. The 62.5, 75 and

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87.5% Friesian grades produced 1 513, 1 362 and 1 507 kg of milk respectively in the same lactation. There was a similar improvement in first calving age but the improvement in calving interval, days open and service period was inconsistent. Overall performance expressed as yield per day (birth to second calving) did not significantly differ among the crossbreds having 50% or more Friesian blood except for those resulting from inter se matings. Level of Friesian inheritance that gave highest yields was estimated to be 60%. Improvement of the present management standards will allow this level to be further increased for higher production levels.

Introduction

Milk yield increases remarkably when tropical indigenous cattle are crossed with exotic breeds like the Friesian and Jersey. Both parental purebreds, the *Bos indicus* indigenous from within the tropics and the *Bos taurus* that are indigenous to the milder climates beyond the tropics, fail to sustain high levels of production in the tropics. The former breed group, survived and reproduced in spite of the lower input quality typical of the tropics although they grew slower and produced less milk. On the contrary, the *B. taurus*, totally unadapted to the hot and humid environment, threatened by parasites and diseases, and fed feeds of a quality typical to the tropics, produced far below their standards in their countries of origin. However, this gap in production could significantly be narrowed only with high capital maintenance costs to house these exotics with reasonable cooling facilities, rigorous control of diseases and by feeding better quality feeds. Such a system could be possible in the tropics only if economic considerations, including labour costs, opportunity costs of resource inputs and current prices of farm products, and existing farming systems are ignored. On the other hand, crossbred cattle of *B. taurus* and *B. indicus* breeds have shown to survive and reproduce well in the tropics with higher levels of growth and milk production, and justify economic considerations.

Crossbreeding has been well-accepted as an effective and quick method to increase milk production and improve the overall performance of dairy cattle in the tropics. However, its long-term strategies have not been fully resolved. A lack of such foresight could be due to several reasons. The final expression of characteristics of dairy cattle is the end product of a complex series of interactions within the genotype, and between genotype and climatic factors, feed quantity and quality, stresses due to diseases and parasites, and economic constraints. Relationship between genotypes and output such as milk, milk constituents, fertility and growth could be clearly shown but is often complicated by these factors. Considerable amount of work on crossbreeding has been done in the tropics and yet further investigations have always been necessary. One reason is the lack of sufficient data of the various crosses designed for a meaningful analysis including that of parental purebreds and backcrosses to both parental breeds.

Although crossbreeding between *B. taurus* and *B. indicus* breeds in Peninsular Malaysia started as early as 1931 (Bunting and Marsh 1934) in a limited way, serious attempts using progeny tested exotic bull semen and artificial insemination, and in larger numbers only began in 1962 by the Department of Veterinary Services (DVS) at the Central Animal Husbandary Station (now known as Institut Haiwan), Agriculture College of Malaya (now Agriculture University of Malaysia) and more recently by MARDI. This was subsequently extended to smallholder dairy farms throughout the country. The local dairy Zebu breed is the Local Indian Dairy (LID) cattle which originated from various Indian breeds. The LID cattle have constantly been upgraded using Red Sindhi and Sahiwal bulls, especially during 1940s–60s in the institutional farms as well as the smallholder farms. Today, the local dairy cattle population stands at 102 572 heads (Anon. 1984) in Peninsular Malaysia, of which 67% are of the LID type. The rest are LID crossbreds, Sahiwal-*B. taurus* crosses imported from Australia and New Zealand (about 20 000 heads) and their progenies.

During the last two decades, the performance of the LID and their crosses with Red Sindhi, Sahiwal, Friesian, Jersey and Australian Illawarra Shorthorn and the Australian Milking Zebu in Malaysia has been reported (Rajagobal 1969; Samuel 1973; Sivarajasingam et al. 1974; Kassim 1977; Lingam et al. 1977; Sivasupramaniam and Mahmood 1981; Sivarajasingam 1982, 1983; Sivarajasingam et al. 1986). The Red Sindhi crossbreeding programme improved the LID only marginally, whereas the *B. taurus* crossbreds showed remarkable improvement. This improvement was not only in milk yield but also in age of sexual maturity and growth. However, there were indications of longer calving intervals and more services to conception after the first calving. Many of these reports were, however, limited by small sample sizes, few crossbred types, few sires of exotic breed and the data were not adjusted for annual and management variations, especially when two or more crossbred types were compared over different time periods. Tests of significance were also limited to only a few reports.

Results on crossbreeding from the rest of the tropics are numerous and have been reviewed by several workers from time to time (Taneja and Bhat 1986). Popular exotic breeds have been Holstein-Friesian, Jersey, Brown Swiss and Milking Shorthorn. There appears to be a general trend in the performance of the F_1, and the various backcrosses although in most cases these trends could not be confirmed due to lack of data and/or robust statistical models. Considerable variations exist in the magnitude of performance caused by environment and management practices. Besides other problems like genotype-environment interactions, solutions to some pertinent questions have still not been satisfactorily answered. The magnitude of additive versus non-additive genetic effects in specific environments is useful information that is now lacking in the planning of future strategies. Many of the results hitherto available are insufficient to define breeding approaches after the F_1 generation and the optimum exotic level of inheritance.

This article describes the crossbred population characteristics, including distribution and performance of the various Friesian-LID crossbred cattle for several traits, and estimate optimum range of Friesian inheritance in these hybrid generations.

Materials and methods

Breeding

The data for this project were gathered from the Institut Haiwan farm of DVS at Keluang, Johore. The base population in this farm originated from the LID cows which were constantly upgraded using Red Sindhi and Sahiwal semen from India since 1950 until 1962. Improvement in production in this programme was marginal (Rajagobal 1969; Sivarajasingam et al. 1974). The DVS then embarked on the crossbreeding programme using mainly Holstein-Friesian semen from Australia besides other *B. taurus* breeds such as Jersey, Australian Milking Zebu and Shorthorn. Purebred Friesian cows and bulls (F100) were also imported from the same source for comparative studies (Lingam et al. 1977). The high grade Red Sindhi and the LID cows that were brought into the farm from time to time, were mated using Friesian semen. The F_1s (F50) were mated to both parental breeds at random to create the backcrosses (F25 and F75). Mating among the dissimilar crossbreds resulted in 62.5% Friesian (F62.5), 87.5% Friesian (F87.5) and 37.5% Friesian (F37.5). The F_1 crosses were also mated by inter se resulting in F_2s (F50). Because the *B. indicus* component of the crosses was derived randomly from unselected LID, LID-Sindhi and LID-Sahiwal grades and it was a difficult task to differentiate among them, they were grouped and referred here simply as Zebu (F0).

Data

The performance records (from 1969 to 1983) were collected from Institut Haiwan. From a set of over 1 300 first lactation milk yield heifer records, only 639 were used in this study covering Friesian crosses. Records having uncertain pedigree information, incomplete lactation records, missing information and those suspected to be from improper recording and of heifers affected by disease were removed. There were 551, 476, 493, 551 and 293 observations on first calving age, calving interval, days open, first service age and first service period respectively.

Traits and restrictions

Milk yield was measured twice daily. Total milk (TM) yield was the sum for the whole lactation length (LL), whereas the 120-day yield (Y120) was the total yield during the first 120 days of lactation. First calving age (CAge) was recorded in days; calving interval (CI), defined as the period between the first and second calving, was also recorded in days. First service age (SA) was the period in days from birth to first observation of heat followed by artifical insemination. The service period (SP) is the difference in days between the first service age and first calving age less 280 days which was assumed to be the mean gestation period. Days open (DO) was calculated by subtracting 280 days from CI. Measures beyond the following ranges were assumed missing: LL $<$ 7 or LL $>$ 400; CAge $<$ 540 or CAge $>$ 1 500; CI $<$ 302 or CI $>$ 1 100; DO if CI $>$ 290; SA $<$ 260; SP $<$ 0. Yield per day calving interval (YC) was calculated as TM per CI kg, whereas yield per day up to second calving (LY) was TM per (CAge + CI) kg. Summary statistics included all records of TM but genetic analysis using statistical models used all TM values that were derived from lactations greater than 30 days only.

Climate and environment

The equatorial climate in West Malaysia is typified as hot and humid. The rainfall, temperature and humidity patterns from 1971 to 1984 at the station was studied in detail. Although no definite trend was observed, rainfall fluctuated with a distinct drop below 5 mm/day in January, February, March, May, June and July. These months were classified as dry months for statistical analysis. The farm is situated about 2° 1' N, 103° 10' E and at 88 m above sea level. The environmental variables covering the period of study were recorded daily. The overall mean maximum, average and minimum temperatures were 31.1, 25.9 and 22.7 °C respectively. The respective mean ranges were 20.0−35.8, 23.0−32.1 and 19.3−27.1 °C. Similar overall means and ranges (maximum and minimum) for relative humidity were 82.3% and 99.8−65.0% and evaporation rate 3.2 and 1.6−6.5 .1 mm/day. Mean total annual rainfall was 2 069 mm and ranged from 1 305 mm to 2 682 mm.

Management

A uniform management system was given to all crossbreds, Zebu and Friesian purebred cattle. They were allowed to graze in the pasture after the morning milking until just after noon when they were driven to their feeding stalls for fodder and concentrate feeding. Second milking was between 1700 h and 1800 h after which they were night grazed overnight. Pasture grasses included a variety of tropical species like *Paspalum* spp. and *Axonopus* spp. besides improved varieties like guinea grass *(Panicum maximum)*. The average dry matter (DM) of these grasses ranged from 14% to 21% with a mean crude protein (CP) of 13%. Fodder grass was mainly napier grass *(Pennisetum purpureum)* and guinea which are often mixed with other local grasses. The DM of fodder averaged 20–25% having an average CP of 9–13%. Feed supplements (DM 89%) with an average CP of 15% and 70% total digestible nutrient (TDN) were given to all milking animals at the rate of 1 kg for every 4 kg of milk.

Crossbred and Friesian cows were machine-milked, whereas the Zebus were hand-milked with calf at the foot. Because the study was aimed to measure the milk produced that was actually available for human consumption, no adjustment was made for the amount consumed by the calf. However, it would have been desirable to measure variation of milk let-down in the whole population. However, such yield records were not completely available.

Calves of crossbred dams were weaned a week after birth. All calves were maintained in calf pens and fed with milk replacers (DM 89%, CP 18% and TDN 72%) up to at least 6 weeks. They were then raised in groups with ad lib. grass and about 0.5 kg of supplement per day until 1 year old.

Proper health care was maintained, and they were regularly sprayed against tick infestation and drenched against local internal parasites.

A programme of heat detection once in the morning and another in the evening was practised daily. Any sign of heat was followed by artificial insemination on the same day if observed in the morning or the following day otherwise.

Statistical analysis

The model, $y_{ijkl} = u + s_{ij} + b_1 a_{ijkl} + b_2 a^2_{ijkl} + g_k + e_{ijkl}$ was used for the analysis to detect difference between crosses in total milk (TM) yield. y_{ijkl} represents a record of first lactation milk yield, u is the population mean, s_{ij} is the fixed effect of j^{th} season (dry vs. wet) within the i^{th} year of calving. a is the age of first calving of the l^{th} heifer and a^2 its squared term with b_1 and b_2 the respective linear and quadratic regression coefficients. g_k is the fixed effect of the k^{th} genetic group and e_{ijkl} is the random error N (O, σ^2e). A further restriction for milk yield was introduced. TM, Y120, YC and LY were deleted if lactation was shorter than 30 days. The same model was used in the analysis of the other traits (except CAge). However, as CAge (both linear and quadratic) was not significant (except for DO), the model was reduced to exclude this effect. Therefore, all lactation records were used even if first CAge records were missing.

A covariate model was used to plot the performance on the level of Friesian inheritance. As in the previous model, season within year was fixed and level of Friesian inheritance was an independent effect in both the linear and quadratic forms. The dependent variables were the observations on the animals concerned. The regression coefficients were significant ($p < 0.05$).

Results

Distribution of calvings by year and month

The calving distribution of heifers whose milk yield records were used in this analysis is given in *Table 1*. It was assumed that the observations culled during the editing process were randomly distributed. The distribution does not show any trend except that the number of animals was reduced during later years. This was due to the importation of Sahiwal-*B. taurus* crosses from Australia and New Zealand, a comparative performance of which is now being pursued.

The distribution by month showed a somewhat increased calving in January and again between August and November *(Table 2)*. However, there was no definite calving pattern and artificial insemination was carried out as soon as the animal was observed to be on heat.

Distribution of genetic groups

The observations were classified by year within the genetic groups to compare how they were distributed over the period of data recording. The results in *Table 3* showed that the animals of the various genetic groups were spread over several years overlapping each other. The data were therefore connected for meaningful comparisons. A total of 174 sires were used randomly. Since breeding values were not estimated, the sires were not selected except for the purebred Friesian semen from Australia. The same applied to females as they were heifers.

Distributions within genetic groups

The proportion of animals within one standard deviation is given for TM, LL and CAge for some genetic groups *(Table 4)*. For all the traits, the proportions fall close to 68.3%, typical of a normal distribution. Less than 15% of the purebred Zebu (LID and LID-Sindhi) heifers produced more than 1 000 kg of milk, whereas more than 53% of the crossbreds gave more than 1 000 kg of milk. Smaller proportions (13%) of F_1 and F75 Friesians (75% Friesian) gave more than 2 000 kg of milk compared with F62.5 Friesian crosses.

Table 1. Distribution of calvings by year

Year	No. of calvings
1969	4
1970	110
1971	43
1972	71
1973	53
1974	67
1975	84
1976	26
1977	31
1978	20
1979	25
1980	42
1981	26
1982	15
1983	22

Table 2. Distribution of calvings by month

Month	No. of calvings
Jan.	60
Feb.	37
Mar.	45
Apr.	45
May	55
June	55
July	46
Aug.	62
Sept.	53
Oct.	64
Nov.	71
Dec.	46

Table 3. Distribution of genetic groups by year and sires

Genetic group	Period	No. of sires
F0	1969–78	24
F25	1973–80	5
F37.5	1979	2
F50 (F_1)	1970–83	89
F50 (F_2)	1972–80	6
F62.5	1976–83	2
F75	1970–83	39
F87.5	1979–83	5
F100	1969–80	2

Table 4. Proportion of animal levels of performance within genetic groups

Trait	Proportion of animals (%)				
	F0	F50 (F_1)	F62.5	F75	F100
TM within 1 SD	63.7	67.0	60.0	67.0	70.4
LL within 1 SD	63.0	62.3	67.0	64.1	70.2
CAge within 1 SD	62.9	68.3	70.9	69.6	71.4
TM >1 000 kg	13.1	53.0	59.7	52.9	36.5
TM >2 000 kg	0.0	13.1	20.0	13.0	2.8

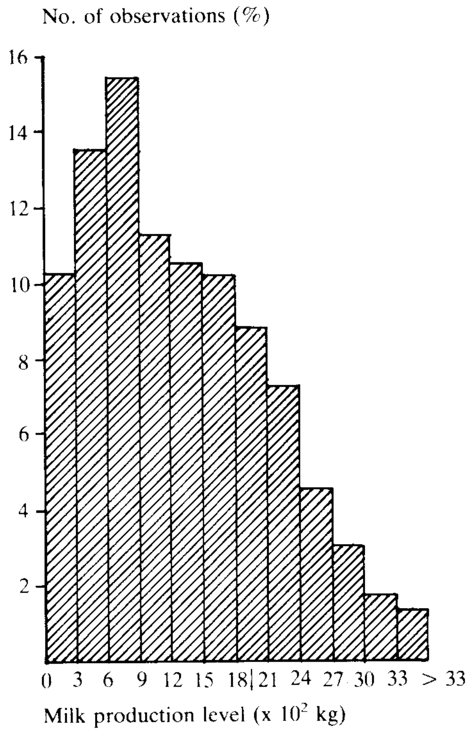

Figure 1. Distribution of total milk yield for F_1 crosses

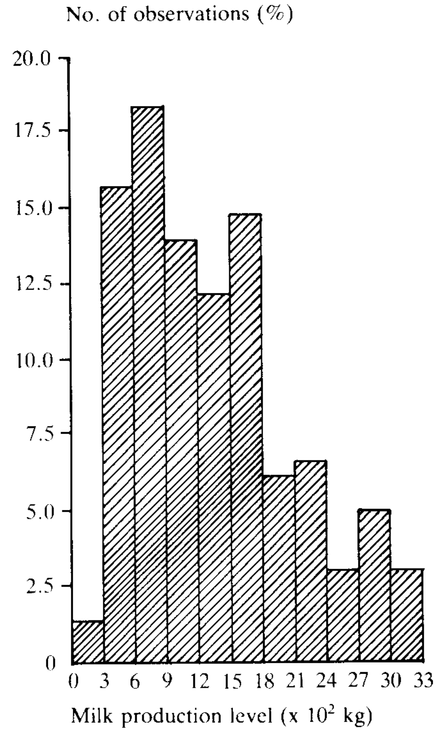

Figure 2. Distribution of total milk yield for F75 Friesian crosses

The histogram for milk yield and LL of F_1 Friesian and F75 Friesians are given in *Figure 1, Figure 2, Figure 3* and *Figure 4*. There was a slight skewedness to the left in *Figure 1* and *Figure 2* for milk yield while LLs were more normally distributed. The modes for F_1 and 75% Friesian milk yield were 600–900 kg. These crosses also had similar modes for LL of 150–200 days. A total of 19.4% of all lactations in the data was less than 120 days.

Phenotypic performance of crossbreds

A summary of the performance of the various crossbreds are given in *Table 5* and *Table 6*. These tables present means, variances, ranges and coefficients of variation (C.V.). These statistics are useful for comparisons with other local literature where similar information are presented without adjustment for environmental variations. The C.V. for TM was considerably greater than the C.V. in yield within the first 120 days of lactation. Although the F62.5 and F87.5

Table 5. Simple statistics of production traits

Trait	F0	F25	F37.5	F50 (F_1)	F50 (F_2)	F62.5	F75	F87.5	F100
TM									
n	122	7	2	381	11	18	76	5	17
Mean (kg)	685	1 010	661	1 309	542	1 513	1 362	1 507	1 112
SE	37	425	619	44	145	168	90	297	149
Min.	27	147	216	14	92	437	196	346	283
Max.	1 505	2 105	933	4 901	1 517	2 362	2 819	1 711	2 333
C.V. (%)	60	83	88	65	89	47	58	44	55
Y120									
n	68	5	1	300	9	14	72	5	13
Mean (kg)	547	766	549	775	406	840	681	786	693
SE	22	167	–	17	77	70	34	142	75
Min.	143	271	–	229	149	299	181	254	260
Max.	836	1 018	–	1 700	767	1 141	1 252	879	1 154
C.V. (%)	33	49	–	37	57	31	42	40	39
YC									
n	101	6	2	276	7	8	60	4	12
Mean (kg)	1.43	2.10	1.61	3.37	0.99	3.45	3.02	3.11	2.13
SE	0.09	0.79	0.95	0.13	0.23	0.78	0.24	0.76	0.37
Min.	0.04	0.32	0.57	0.02	0.27	0.69	0.52	0.71	0.68
Max.	3.32	4.35	2.23	10.82	1.71	5.26	7.14	3.54	4.07
C.V. (%)	66.6	70.0	83.5	64.3	60.6	64.6	63.3	49.2	59.8
LY									
n	60	6	1	266	7	6	53	4	12
Mean (kg)	0.46	0.66	0.67	0.97	0.28	0.98	0.85	0.94	0.69
SE	0.03	0.26	–	0.03	0.07	0.28	0.07	0.25	0.11
Min.	0.02	0.09	–	0.01	0.06	0.23	0.17	0.21	0.17
Max.	0.91	1.33	–	2.91	0.49	1.64	1.90	1.22	1.33
C.V. (%)	58.8	97.8	–	62.4	68.1	67.8	58.5	53.4	55.4
LL									
n	82	7	2	337	11	8	63	5	14
Mean (day)	201	209	208	217	173	235	246	250	198
SE	10	42	103	6	24	34	11	23	21
Min.	12	75	78	8	82	73	52	164	99
Max.	395	375	338	400	351	368	399	291	382
C.V. (%)	49	54	88	46	45	41	36	20	40

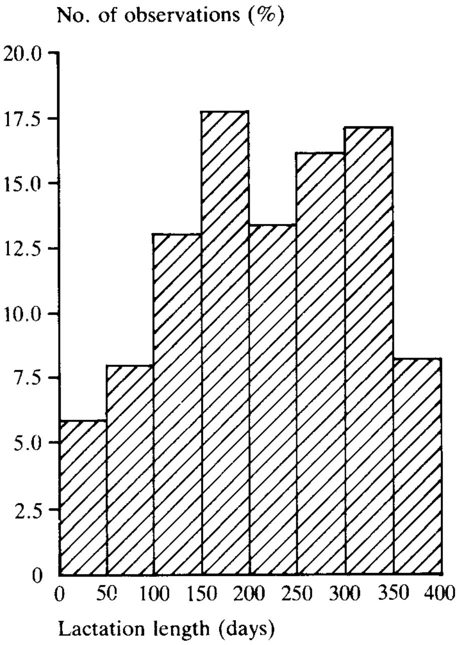

Figure 3. Distribution of lactation length for F_1 crosses

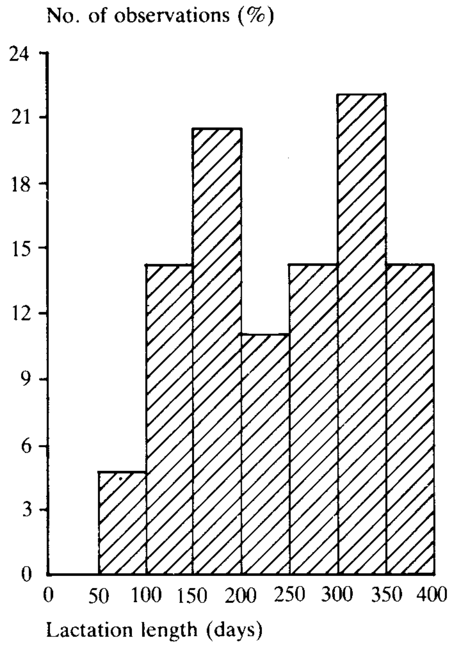

Figure 4. Distribution of lactation length for F75 Friesian crosses

Friesian crosses had the highest total yields, the F_1 halfbreds had a maximum yield of 4 901 kg, a minimum yield of 14 kg and LL of 8 days. There was less variation in reproduction among the various genetic groups *(Table 6)*. The F_1s were generally superior to the other crosses for the reproductive traits given in this table.

Effects of year and season

The season-within-year effects were highly significant ($p < 0.001$) for all traits except DO. As mentioned earlier, CAge (linear and quadratic) when included in the model was insignificant ($p > 0.10$) except for DO where it was significant at $p = 0.05$, and was therefore removed. Least square means of production traits for the animals that calved during the wet seasons were generally higher than that for dry seasons and the least square means during the later years were higher than during the earlier years.

Effects of genetic groups

The genetic-group effect was highly significant for all traits ($p < 0.001$) except for LL and SP. Linear and quadratic contrasts were also insignificant ($p > 0.05$) for these traits but were highly significant ($p < 0.001$) for all other traits and significant ($p < 0.05$) for TM yield.

The least square means estimated from the model for each trait are given in *Table 7* (production traits) and *Table 8* (reproductive traits). The various genetic groups were compared to the F0 and the F50 (F_1) crossbreds to note the advantage of crossbreeding and also the direction that needs to be taken after the F_1 generation. All the hybrid crossbreds (excluding F_2) were significantly superior to the parental purebreds and the F_2 generation. This was, however, not observed for the LL and SP. Although the hybrids did not differ significantly, those with 50% or more Friesian blood showed superior performance in milk yield and

Table 6. Simple statistics of reproductive traits

Trait	F0	F25	F37.5	F50 (F_1)	F50 (F_2)	F62.5	F75	F87.5	F100
CAge									
n	70	7	1	362	11	15	66	4	15
Mean (days)	1 219	1 155	1 197	1 039	1 174	1 114	1 145	1 057	1 047
SE	17	49	–	7	46	40	23	64	36
Min.	972	945	–	552	877	877	709	878	894
Max.	1 480	1 324	–	1 497	1 458	1 405	1 496	1 170	1 328
C.V. (%)	12	11	–	13	13	14	16	12	13
CI									
n	101	6	2	276	7	8	60	4	12
Mean (days)	503	535	397	442	454	469	511	461	551
SE	13	96	21	7	46	44	20	42	46
Min.	319	359	376	310	343	349	336	339	355
Max.	925	982	418	1 071	657	729	1 063	530	813
C.V. (%)	26	44	8	28	27	26	31	18	29
DO									
n	102	6	2	287	8	8	64	4	12
Mean (days)	232	255	117	159	141	189	231	181	271
SE	16	96	21	8	52	44	24	42	46
Min.	39	79	96	0	0	69	0	59	75
Max.	1 148	702	138	1 127	377	449	1 055	250	533
C.V. (%)	68	92	25	80	70	65	84	46	59
SA									
n	81	7	2	346	9	17	69	5	15
Mean (days)	985	699	953	732	846	863	902	951	756
SE	50	51	351	12	60	73	41	264	103
Min.	595	532	602	300	587	469	458	615	517
Max.	4 559	943	1 303	3 629	1 136	1 847	2 518	2 004	2 126
C.V. (%)	45	19	52	31	21	35	38	62	53
SP									
n	82	7	2	265	7	15	54	3	13
Mean (days)	101	176	207	74	82	110	127	125	118
SE	17	50	108	6	40	38	25	54	32
Min.	0	7	99	0	2	3	0	32	3
Max.	616	353	315	526	305	544	1 100	224	321
C.V. (%)	70	75	74	74	97	87	91	74	75

Table 7. Least square means and standard errors for production traits by genetic groups

Genetic group	TM		Y120		YC		LY		LL	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
F0	812.0[1]	92.7	424.7[1]	39.1	1.58[1]	0.24	0.399[1]	0.081	200.0	14.8
F25	1 194.5	256.8	687.7	104.9	2.40	0.75	0.738	0.279	216.5	37.0
F37.5	930.4	481.0	673.9	235.4	3.00	1.31	0.881	0.524	207.1	69.3
F50 (F_1)	1 270.7*	48.4	763.3*	20.2	3.38*	0.15	0.951*	0.046	210.1	6.9
F50 (F_2)	775.1[2]	202.1	547.4[1]	79.0	1.76[2]	0.69	0.501[2]	0.200	167.8	23.1
F62.5	1 298.4	237.6	805.9*	89.7	3.35	0.65	0.821	0.216	226.0	34.2
F75	1 303.6*	92.6	732.0*	34.8	3.60*	0.26	0.986*	0.081	233.5	13.3
F87.5	1 271.4	314.4	749.6[+]	109.3	3.84[+]	1.00	1.095[+]	0.275	235.2	45.3
F100	1 021.2	185.8	660.1[+]	75.6	2.10[2]	0.55	0.616[2]	0.159	177.9	26.7

*significantly different from FO at $p < 0.01$
[+]significantly different from FO at $p < 0.05$
[1]significantly different from F_1 at $p < 0.01$
[2]significantly different from F_1 at $p < 0.05$

Table 8. Least square means and standard errors for reproductive traits by genetic groups

Genetic group	CAge		CI		DO		SA		SP	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
F0	1 300.2[1]	23.6	494.6[1]	20.4	230.5	23.4	1 141.7[1]	43.8	138.0	29.9
F25	1 148.0[1]*	53.1	499.2	56.2	207.3	65.4	631.7*	109.2	161.5	57.4
F37.5	1 261.7	138.0	374.8	97.9	117.6	113.3	1 099.8	207.4	269.4	98.7
F50 (F_1)	1 023.8*	11.0	429.7*	11.2	139.8*	12.8	741.2*	22.2	130.7	16.5
F50 (F_2)	1 130.6[2]*	41.9	428.9[1]	51.3	103.1[+]	55.7	790.2*	95.1	104.1	61.3
F62.5	1 097.7*	38.0	460.6	48.5	177.6	56.3	771.9*	72.9	161.8	55.0
F75	1 129.4[1]*	19.3	477.6[2]	19.5	200.1[1]	22.0	877.7[1]*	38.0	190.7[2]	26.5
F87.5	1 079.7*	72.0	457.3	71.2	193.2	82.2	1 016.4[2]	133.7	194.0	85.4
F100	1 150.2[1]*	37.2	575.0[1+]	40.7	300.8[2]	47.3	923.3[1]*	76.5	164.7	48.8

*significantly different from F0 at $p < 0.01$
[+]significantly different from F0 at $p < 0.05$
[1]significantly different from F_1 at $p < 0.01$
[2]significantly different from F_1 at $p < 0.05$

first CAge. The YC was 3.38 kg amongst the F_1 crosses and was 3.35, 3.60 and 3.84 kg for the F62.5, F75 and F87.5 crossbreds respectively. LY which is a function of TM yield, first CAge and CI rose from 0.951 kg in the F_1 crosses to about 1.1 kg for the F87.5.

From *Figure 5* to *Figure 8,* the linear and quadratic regression coefficients were significant ($p < 0.05$) for all traits except for LL and first SP. Except for the latter trait and DO, the year-season effects were also highly significant ($p < 0.01$).

Discussion

Although crossbreeding is generally accepted as a solution to low productivity standards of indigenous cattle, it is also the beginning of a series of challenges to the animal geneticists and breeders. The dilemma of the choice of strategies after the F_1 crosses and the consideration of more than one trait are areas of concern.

Approximately two-thirds of the LID (F0), the purebred Friesian and the crossbreds fell within one standard deviation about the mean for milk yield and CAges typical of a normal

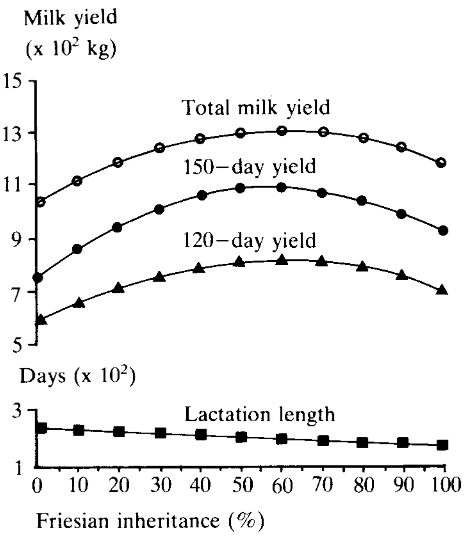

Figure 5. Relationship between milk yield and level of inheritance

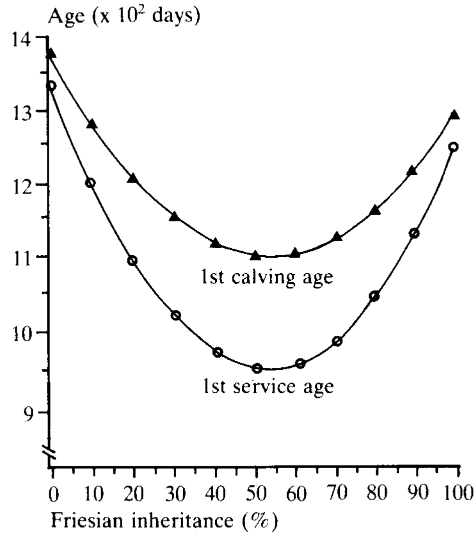

Figure 7. Relationship between first calving age and first service age, and level of inheritance

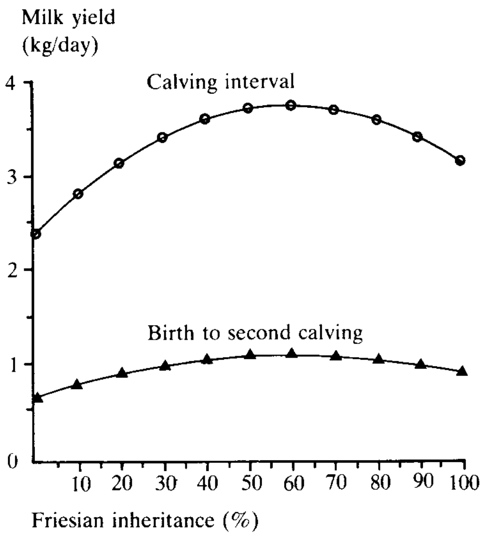

Figure 6. Relationship between yield per day and level of inheritance

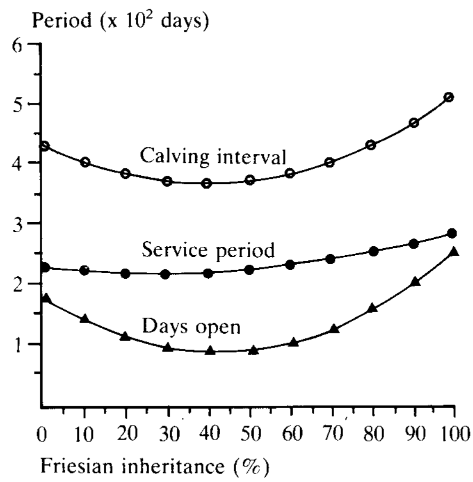

Figure 8. Relationship between post calving reproduction and level of inheritance

distribution. However, the distributions and further tests for normality showed slight skewedness (> -1) to the left but was not significant. Log transformation did not change any levels of significance in the model used to test differences between year and seasons, CAge or genetic groups and therefore transformation was not used.

Mean LLs were generally short in this study and the distribution of LL about the mean was 'flatter' than those for the other two traits mentioned *(Figure 3, Figure 4* and *Table 4)*. Short lactations of less than

120 days were widespread in all classes of Friesian purebreds and crossbreds which were all machine milked. Higher failure rates were reported by Hayman (1972) and Alexander et al. (1984) amongst Sahiwal and Red Sindhi-Jersey crosses and Sahiwal-Friesian crosses in Australia. MacMillan and Pearce (1985) attributed this to age at first calving and have cited the work of Edwards (1984) which showed that heifer groups with lower CAge (< 30 months) had higher failure rates than those calved at later ages. However, in this study, the phenotypic correlation estimates between TM yield and first CAge within genetic groups were small and not significant ($p > 0.05$). The lowest level of significance ($p = 0.0515$) was obtained for the F50 (F_1) group where the estimate was −0.106. Yield within the first 120 days of lactation was also not correlated to age. Similar reports were also made by Mahadevan and Hutchison (1964) among East African Zebu of Boran and Jiddu types and crosses with Guernsey, Jersey and Friesian blood. These Zebu and crossbreds had similar production levels but the mean for first CAges were higher for the crossbreds in this study.

The crossbred cattle have shown remarkable performance, especially in milk yield and first CAge over the LID cows. The improvement in TM yield was as high as 91, 121, 99 and 120% over the F0 or LIDs among the F_1, F62.5, F75 and F87.5 respectively, and 54−61% after adjusting to the environmental variations. This improvement could be due to heterosis in the F_1 generation, and the simple additive effects, especially in the subsequent backcrosses with the Friesian where loss of heterosis was compensated by additive effects. Within year-season regressions of production on percentage of Friesian inheritance *(Figure 5* to *Figure 8)* show a diminishing improvement due to crossbreeding under the present production system. There was little improvement in the LL from 201 days in the F0 to 235 days in the high grade Friesians. The trend for reproductive traits *(Table 8)* was somewhat different with a drastic improvement in the F_1s and a drop in F75 and regaining in the F62.5 and F87.5 generations. The indices YC and LY showed a consistent increase in yield per day in each genetic group having more Friesian inheritance with a maximum among the F87.5. However, reliability of figures in this group could be low due to its small sample size. The F75 crossbreds though producing 1 303.6 kg of milk (adjusted), had significantly ($p < 0.05$) longer CAge and CI than the F_1 or the F62.5 hybrids.

The production figures presented in this study are generally lower than those reported in India but similar to those in Thailand, Sri Lanka and other parts of the tropics (El−Itriby and Asker 1958; Amble and Jain 1966; Buvanendran and Mahadevan 1975; Madsen and Vinther 1975; Meyn and Wilkins 1975; Rao and Nagarcankar 1979; Rao and Taneja 1980). These figures from India for F_1 and other crossbreds were in the region of 2 000−3 500 kg. They were the progeny of high yielding Zebus like Sahiwal, Red Sindhi and Tharparkar. The LID cattle which formed the foundation Zebu parent in these data were a random collection from the main population which was unselected for any economic trait. The reproductive characteristics of the crossbreds were, however, comparable (CI, DO, SA and SP) or even superior (CAge) to those in the above reports. They generally dropped a calf by 36 months and subsequently every 15 months. It was strikingly evident in this study and published literature that the crossbreds, especially the F_1s, were superior in milk yield and first CAge but showed considerable variation in CI and other traits. 'Heterosis' estimates for milk yield from least square estimates were high, 38.6% for TM and 40.7% for Y120. However, these estimates could be considered biased due to the absence of data from reciprocal crosses and small sample size of the Friesian parent. These latter purebreds may have also undergone greater stress than the Zebu parent. Similar estimate of superiority of F_1s over the mean of LID and Friesians for CAge, CI, DO, SA and SP were −16.4, −19.6, −47.3, −28.2 and −13.9 respectively.

Level of milk production and superiority in other traits increased with increasing levels of Friesian inheritance (*Figure 5* to *Figure 8)* which then declined after the maximum was reached. This maximum was estimated by taking the first derivatives of the regression equations with respect to the level of inheritance and solving for the same after setting them to zero. Percentages of Friesian inheritance when performance was maximum were 60.5, 60.2, 61.3, 54.3, 40.9, 42.8, 53.2 and 26.8 for TM, Y120, LL, CAge, CI, DO, SA and SP respectively. Maximums for composite traits like YC and LY were 60.4 and 60.1 respectively. These results show that within the medium level of management provided with minimum protection from heat stresses, highest production levels amongst hybrids could be achieved at about 60% Friesian inheritance.

The F_2 crossbreds dropped by as much as 39% in milk yield from the F_1 generation with a similar trend of lowered performance in LL and CAge. This drop was also experienced in many other herds (Buvanendran and Mahadevan 1975; Bhatnagar et al. 1981). Often this drop was due to loss in heterosis but this explanation did not have substantial basis. In most breeding programmes, the number of F_2 crossbreds was small and does not allow representation of a true picture of genetic segregation and gene recombinations. The F_1 sires used to breed the F_2 crosses were often unselected or untested and could even be below average resulting in the poorer performance of the F_2 (Taneja and Bhat 1986).

More than half, in some cases 72% of the TM yield was produced within the first 120 days of lactation. Van Vleck and Henderson (1961) have shown that part lactation yields gave higher or at least similar estimates of heritability as complete 305-day lactations. In a tropical environment and with long CI, there is a tendency to continue milking in spite of low daily yields, and therefore evaluations from part lactations may be desirable to reduce some of these variations accruing from the environment. The increase in milk yield from F0 (LID) to the F_1 crossbred was 80% during the first 120 days but reduced to 54% over the whole lactation. There was also a marked difference in the drop in milk yield between F_1 and F_2 generations within the whole lactation record (drop of 38.1%) and 120-day yield (drop by only 28.2%) The results, substantiated by overall short LLs, seem to appear that the animals had a low persistency of lactation resulting in lower yields.

It is concluded here that milk and reproductive performances could be considerably improved by crossbreeding the LID or improved local Zebu cattle with Friesian gene pool. Milk yield and first calving and service age show obvious advantages in the crosses, especially at higher levels beyond 50% of Friesian blood, whereas other traits such as CI, SP and DO show considerable variation with better prospects nearer to 50% Friesian inheritance. It could also be speculated that in a different environment the performance levels of all the crossbreds and parental purebreds will be elevated (or depressed) proportionately to the magnitude change in the environment but at a greater rate for crosses with higher levels of Friesian inheritance than those with higher Zebu blood. In other words, the curve in *Figure 5* will generally be moved higher but the shift will be greater on the right hand side than the left. This is because the Friesian genes will be able to respond better to the better environment. However, at higher levels of management and production, limiting factors such as environmental stress like that due to heat and high humidity and low nutrient quality of local feeds may take their toll. Few reports like Amble and Jain (1966) in India, and Madsen and Vinther (1975) in Thailand have shown higher incidence of calf and adult mortality among grades with *B. taurus* blood greater than 50%. The F_1s had low mortality rate similar to that of local Zebu. McDowell et al. (1955) showed stress responses of the 75% Jersey crosses similar to that of contemporary Jerseys under conditions of high temperature and humidity. Similar responses of the F_1 Red Sindhi-Jersey and ¼ Jersey were significantly lower.

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