

# UTILIZATION OF EXOTIC GERMLASM FOR MILK PRODUCTION IN THE TROPICS

J.E.O. Rege

International Livestock Research Institute  
PO Box 5689, Addis Ababa, Ethiopia

## SUMMARY

Results from 80 reports in the literature on crossbreeding in the tropics were summarised to study the relationship between dairy performance and proportion of exotic genes. Grades higher than  $\frac{1}{2}$  exotic did not perform any worse than the  $F_1$  in all traits, except calving interval which was longer in higher grades. The relationship between performance and proportion of European genes differed among breeds. The Friesian crosses were not any better than crosses involving Jersey, Brown Swiss, Ayrshire or Red Dane.  $F_2$  performance was lower than that of  $F_1$ , but subsequent generations ( $F_3$  and  $F_4$ ) were not any worse than  $F_2$ .

**Keywords:** *Bos indicus*, *Bos taurus*, crossbreeding, milk production.

## INTRODUCTION

Crossbreeding with European dairy breeds continue to be widely used as a method for improving the milk production potential of tropical cattle. Previous reviews of dairy cattle crossbreeding results in tropical environments have shown first generation ( $F_1$ ) crosses (50% exotic) to be superior to lower grades (McDowell 1985; Cunningham and Syrstad 1987). Results summarised by Cunningham and Syrstad (1987) showed consistent improvement of milk yield and calving interval with increasing European gene fraction upto 50% and, from then on, slight increase in calving interval but no clear trend in milk yield. More recent studies involving meta analysis of increasingly large numbers of results from the literature (e.g Syrstad 1990; McDowell *et al.* 1996; Syrstad 1996) as well as analysis of individual long-term studies in Asia (Chand 1988; Jadhav *et al.* 1991), Africa (Thorpe *et al.* 1993; Rege *et al.* 1994) and Latin America (Madalena *et al.* 1990) have confirmed the previous results.

Despite the convincing and consistent crossbreeding results, there are hardly any countries which have developed strategies and policies to utilise the advantages of  $F_1$  crosses. Indeed, most developing countries still practise systems of upgrading to higher exotic grades and/or use of pure exotic breeds. Additionally, where composite breeds have been formed in the tropics, the majority have consisted of grades higher than  $\frac{1}{2}$  European inheritance. Thus, the Jamaica Hope is  $\frac{3}{4}$  Jersey, the Brazilian Pitanqueiras is  $\frac{5}{8}$  Red Poll, the Australian Milking Zebu is  $\frac{3}{4}$  Jersey, the Indian Karan Fries is  $\frac{3}{4}$  *Bos taurus*, the Cuban Siboney is  $\frac{5}{8}$  Holstein and the Cuban Mambi is  $\frac{3}{4}$  Holstein. Thus, although  $\frac{5}{8}$  is considered the highest proportion of European inheritance which is compatible with adaptation to the tropical environment (Syrstad 1996), composites of higher grades, especially  $\frac{3}{4}$  exotic, probably predominate. There is need to compare performance of different grades of exotic inheritance produced by

various European dairy breeds under tropical conditions to determine relative performance of genotypes derived from different exotic breeds and appropriate levels of exotic genes for different production systems.

This paper summarises results from 80 crossbreeding studies involving various European dairy breeds in the tropics and uses the results to draw conclusions on possible strategies for utilisation of different European dairy breeds for milk production in the tropics.

## MATERIALS AND METHODS

**Analysis 1.** Results of crossbreeding experiments involving European x indigenous breeds in the tropics (Africa, Asia and Latin America) published in conventional and grey literature in the period 1966 to 1996 were screened. A set of results qualified for inclusion in the study if it satisfied certain criteria: There had to be at least two genotypes (pure indigenous, exotic or cross) with results on one or more of the four primary variables studied; each genetic group had to have at least 10 observations; animals had to be raised on pasture or a similar feeding system; only data collected in tropical developing countries were considered. Preference was given to first lactation records, which were found in most reports reviewed. However, combined lactations were included in cases where only such records were available. Based on these criteria, 80 reports were selected for inclusion in the analyses. Results from these reports were used to create a data set consisting of the following: Codes for exotic breeds used, codes for the source of the data ("data set"), codes indicating proportion of exotic genes and least squares (LS) means for the four traits – lactation milk yield (MY), lactation length (LL), age at first calving (AFC) and calving interval (CI). Annual milk yield (AMY) was calculated for records with MY and CI as  $(MY \times 365) / CI$ . LS means for genetic groups were estimated by fitting constants for the variables "data set" and "genetic group". Number of observations used in published estimates were used as weights in the meta analyses. In addition to combined analyses of all crosses in the data, separate analyses were done for individual exotic breeds with sufficient data. Table 1 summarises number of data sets used for each exotic breed and trait. Heterosis estimates were obtained for the combined data and for individual exotic breeds as deviation of mid-parent mean from that of the  $F_1$ .

**Table 1. Summary of number of data sets used in the meta analysis**

Trait	No. of data sets involving <sup>a)</sup>				
	Friesian	Jersey	Brown Swiss	Ayrshire	Red Dane
Milk yield	67	55	54	46	46
Lactation length	45	37	37	32	32
Age at first calving	35	27	27	25	24
Calving interval	44	32	33	27	27
Annual Milk yield	44	32	33	27	27

<sup>a)</sup>Some data sets had multiple breeds

**Analysis 2.** Data used in analysis 2 was a subset of that used in analysis 1. It included data from studies which had  $F_1$  crosses involving two or more of the five *Bos taurus* breeds (Table 1) crossed with the same indigenous breed. A total of 36 data sets were included in this set of analyses to compare the five European breeds on the basis of  $F_1$  performance.

## RESULTS

**Effect of upgrading.** Results of the meta analyses of the combined data are summarised in Table 2 and Figure 1. These results show consistent increase in milk yield with increasing levels of exotic genes upto  $\frac{1}{2}$  exotic inheritance. Grades with higher than  $\frac{1}{2}$  exotic genes were not different from the  $F_1$  in a consistent pattern. Indeed,  $\frac{7}{8}$  and pure exotic genotypes tended to be superior in milk yield. Estimates for  $\frac{15}{16}$  and  $\frac{31}{32}$  exotic genotypes were associated with large standard errors but were not different from the other high grades. Thus, these data provided no evidence of declining MY beyond  $\frac{1}{2}$  exotic inheritance. LL increased over the entire range of exotic grades, albeit with up-and-down swings. As was the case with MY, AFC improved with increasing proportion of exotic genes upto the  $\frac{1}{2}$  level, but there was no difference among the higher grades. CI decreased upto the  $\frac{1}{2}$  level of exotic inheritance, then exhibited an increase in grades higher than  $\frac{1}{2}$ . AMY followed the pattern of MY.

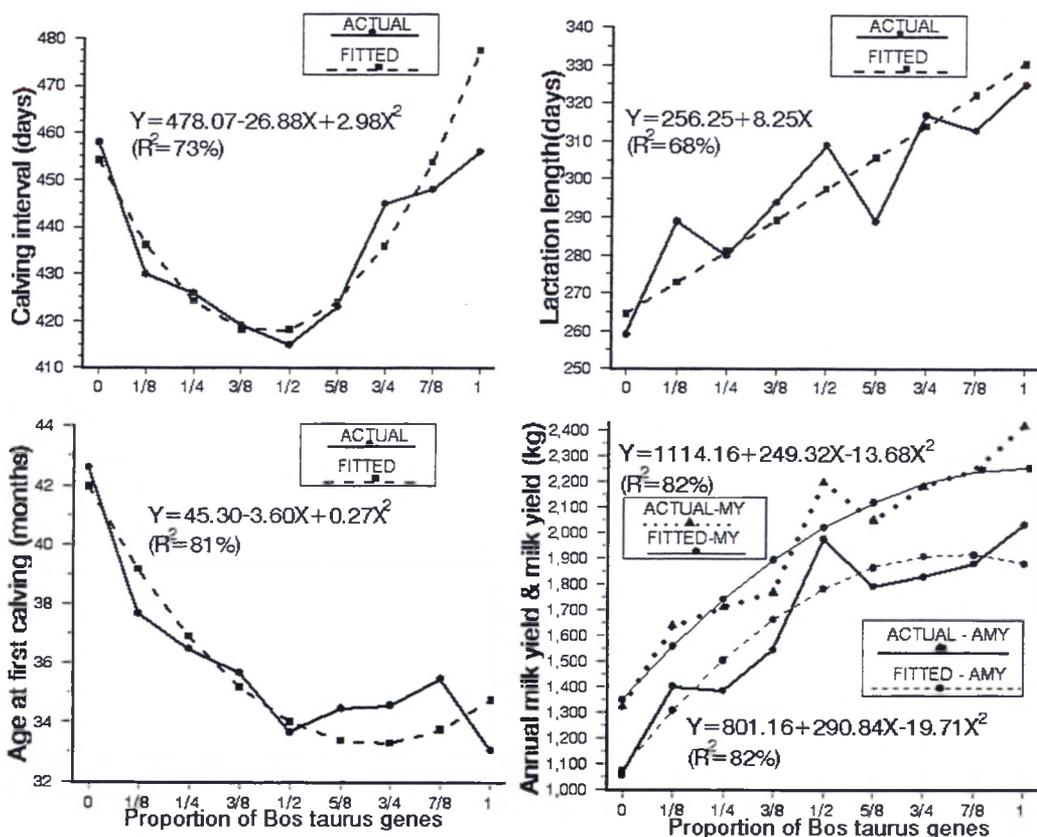
**Table 2. Least squares means of traits studied (and s.e) for genetic groups estimated from a total of 80 data sets**

Prop.of <i>Bos taurus</i>	MY(kg)	LL (days)	AFC (months)	CI (days)	AMY(kg)
0	1322( 46.7)	259( 5.5)	42.6(0.55)	458( 5.8)	1058( 57.2)
1/8	1637(153.5)	289(16.8)	37.7(2.02)	430(18.3)	1402(181.5)
1/4	1709( 68.7)	280( 8.4)	36.5(0.85)	426( 8.8)	1384( 87.2)
3/8	1766( 98.9)	294(14.6)	35.7(0.96)	419( 9.4)	1544( 93.5)
1/2( $F_1$ )	2195( 30.1)	309( 3.6)	33.7(0.35)	415( 3.6)	1973( 35.5)
5/8	2046( 78.9)	289(11.8)	34.5(0.86)	423( 8.1)	1790( 80.0)
3/4	2179( 43.5)	317( 5.7)	34.6(0.45)	445( 4.8)	1828( 47.5)
7/8	2243( 83.0)	313(12.4)	35.5(0.86)	448( 8.5)	1880( 84.4)
15/16	2091(171.4)	312(33.5)	34.5(1.96)	466(21.8)	1555(217.1)
31/32	1835(241.1)	-	35.8(2.75)	460(30.7)	1299(305.5)
1	2420( 59.1)	325( 7.6)	33.1(0.68)	456( 7.0)	2031( 69.8)
$F_2$	1725(105.1)	283(10.1)	37.1(1.05)	452( 9.9)	1452( 98.8)
$F_3$	1860(177.4)	309(17.2)	38.0(2.99)	441(18.4)	1565(182.6)
$F_4$	2659(357.7)	353(34.7)	39.6(2.99)	-	-

Figure 1 shows good fit of quadratic functions for MY, AFC, CI and AMY and a linear function for LL. The plots (of the LS means) were remarkably similar to those obtained using results of Cunningham and Syrstad (1987) and Syrstad (1996).

**Performance of *inter se* generations.** Results in Table 2 show that MY of F<sub>2</sub> cows was 21% (470kg) less than that of F<sub>1</sub> animals while corresponding declines in LL, AFC, CI and AMY were 8% (26 days,) 10% (3.4mo), 9%(37 days) and 26% (521kg). There was no decline in the performance of F<sub>3</sub> below that of F<sub>2</sub> in any of the traits. Estimates available for F<sub>4</sub> cows for MY and LL also showed small but non-significant differences from those of F<sub>2</sub> and F<sub>3</sub> means.

**Differences between exotic breeds.** The relationship between performance and proportion of exotic genes differed depending on the exotic breed used. Although the general trends in the relationship were similar to those obtained for the combined analyses, there were obvious differences in the shapes of the plots (Figure 2). For all the breeds, there was no evidence in any of the traits, except CI, for declining performance beyond 1/2 exotic inheritance. Even CI showed a strong and consistent decline only in the Red Dane, the Friesian and Brown Swiss, but the upward trend in the latter was weaker and was only evident in 3/4 grades and higher.



**Figure 1. Relationship between performance and proportion of exotic genes for data of all exotic breeds combined**

For any one trait, an attempt to fit identical regression functions for crosses derived from different exotic breeds was unsuccessful. The relationship between performance and level of exotic inheritance seemed to differ among breeds (Figure 2). For example, while the Red Dane had an excellent quadratic fit ( $R^2 > 95\%$ ) for CI and AMY, corresponding quadratic fits for the Friesian breed were poor, with  $R^2$  of 3 and 15%. For MY, the best fitting function for the Red Dane was linear ( $R^2 = 61\%$ ); the linear function for MY for the Friesian had a poor fit ( $R^2 = 22\%$ ). Additionally, other than the Red Dane which had a truly linear function for LL, the LL curves for the other crosses were not linear. Thus, the good linear fit for LL in the combined analysis (Figure 1) was simply a result of averaging the different curves in Figure 2. For all traits, the present results showed that conclusions from combined analyses of all crosses could be misleading.

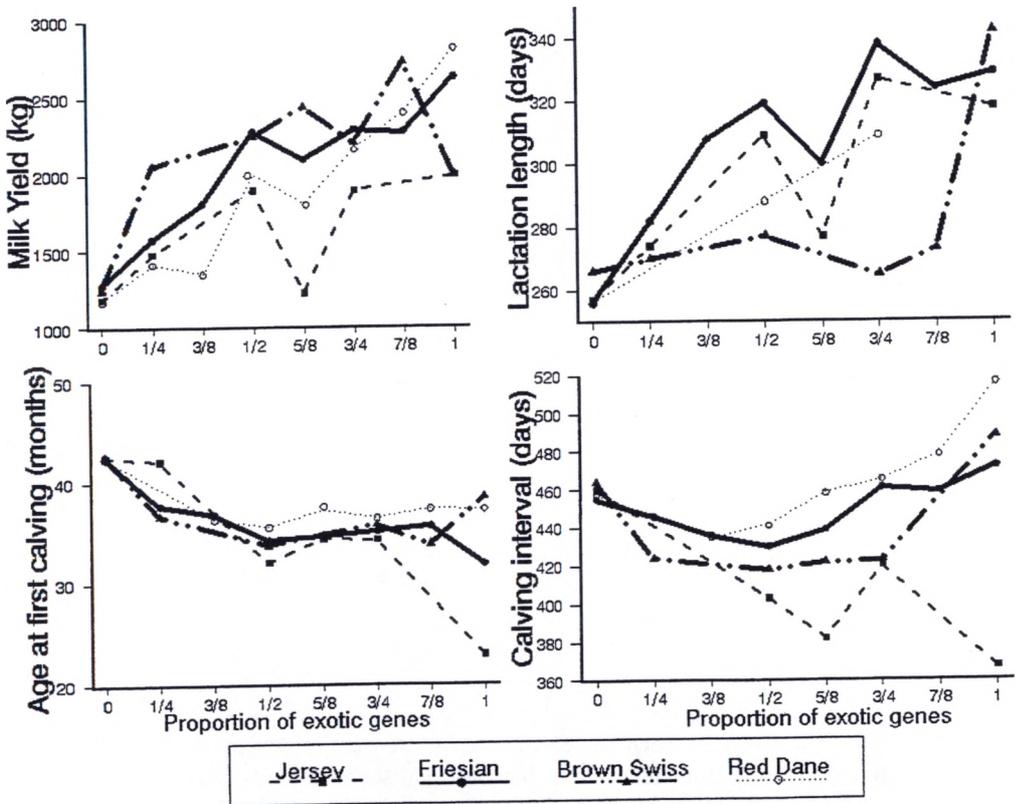


Figure 2. Relationship between performance and proportion of exotic genes for four exotic breeds

A comparison of F<sub>1</sub>s produced by different European breeds showed that the Friesian F<sub>1</sub> MY, LL and AMY were numerically superior to those of other breeds, but the difference between the Friesian and the second ranking F<sub>1</sub> was not significant for any of these traits. The Jersey and the Ayrshire F<sub>1</sub>s calved at the earliest ages and had the shortest mean calving intervals.

**Heterosis estimates.** Heterosis estimates from the combined data were within the range in the literature (e.g. Martinez *et al.* 1988; Madalena *et al.* 1990; Thorpe *et al.* 1993; Rege *et al.* 1994; Mackinnon *et al.* 1996). Thus, the F<sub>1</sub>s were 324 kg (17.3%) better than the mid-parent MY, and LL was 17 days (5.8%) longer, AFC was 4.2 months (11%) less, CI was 42 days (9%) shorter and AMY was 428 kg (27.7%) higher. However, there were large differences in heterosis estimates between individual exotic breeds (Table 3). The estimate of -27 days (8.9%) for LL for the Brown Swiss was undesirable. However, for the other traits, the Brown Swiss consistently had larger (and desirable) heterosis than the other breeds. The Red Dane had the smallest heterosis estimate (3kg, 0.2%) for MY. The Jersey had the smallest heterosis for AFC (-0.7 mo, -2.1%) and CI (-11 days, -2.7%). The AMY heterosis estimate for the Jersey (196 kg, 13.5%) and Red Dane (184 kg, 12.9%) were similar.

**Table 3. Estimates of heterosis in F<sub>1</sub> animals for individual European breeds**

Trait	Heterosis estimate							
	Friesian		Jersey		Brown Swiss		Red Dane	
	raw	%(MP) <sup>a)</sup>	raw	%(MP)	raw	%(MP)	raw	%(MP)
MY(kg)	326	16.7	340	21.9	627	38.7	3	0.2
LL(days)	26	8.9	21	7.3	-27	-8.9	-	-
AFC (months)	-3	-8.1	-0.7	-2.1	-6.8	-16.8	-4.3	-10.8
CI (days)	-34	-7.3	-11	-2.7	-58	-12.2	-46	-9.4
AMY (kg)	409	26.4	196	13.5	852	72.4	184	12.9

<sup>a)</sup>Heterosis as % of midparent (MP) value

## DISCUSSION

**Comparison of genotypes.** The result that performance increases with proportion of exotic genes upto F<sub>1</sub> is consistent with those of previous studies (Cunningham and Syrstad 1987; Syrstad 1990; Syrstad 1996). However, the results of grades higher than ½ exotic in the present study has revealed that, except for CI, performance continued to increase with increasing proportion of exotic genes, but the rate of increase was variable among traits. While it was essentially linear for LL, for MY, AFC and AMY, it was linear upto ½ but levelled off in grades higher than ¾, but at different rates. McDowell (1972) estimated that differences in milk yield between European x zebu crossbreds and pure Holsteins would be small at moderate production levels but that pure Holsteins would exceed the crossbreds if higher energy was available to allow higher performance. Studies in Brazil (Madalena 1981) have shown that F<sub>1</sub>s generally have higher MY and shorter CI, but that their superiority over

higher grades declined as the production level increased in response to improved production environment. Another point revealed by these results was that, at the same level of indigenous genes, crosses of different European breeds differed in their performance.

The superiority of the Friesian as a dairy animal in high-input, temperate environments is well established. However, the present results indicate that, under tropical conditions, the Friesian and its crosses are not necessarily superior. Among the pure exotic breeds, the Red Dane was superior in MY, not different from the Friesian in AMY, but had poor reproductive performance (AFC and CI). The Jersey was top in AFC and CI but had lower MY than the other breeds. However, because of its short CI, its AMY was not different from that of the Friesian or the Red Dane. Although comparative performance of specific genetic groups (1/8, 1/4, 5/8, etc.) produced by the different exotic breeds were variable, evidence for Friesian superiority was lacking. Moreover, an examination of the performance of pure indigenous breeds used in crosses with the different exotic breeds indicated that the Friesians may have been exposed to slightly better environments or bred to better mates than the other exotic breeds. Taken together, these results raise doubt about the appropriateness of the Friesian for dairying in tropical smallholder systems. Indeed, consideration of the differences in mature cow weight between these exotic breeds would further diminish any advantage of the Friesian in these systems.

Syrstad (1989) concluded that performance of  $F_2$  was worse than that of  $F_1$  in all traits studied viz MY (by 452 kg representing 24%), LL (12 days, 4%), AFC (2.3 months, 7%) and CI (26 days, 6%). Such declines in performance following *inter se* mating of  $F_1$ s have been attributed to a reduction in heterozygosity. However, for MY, this explanation has been considered insufficient and a breakdown in epistatic gene effects (recombination loss) has been suggested as additional explanation for the magnitude of decline experienced (Syrstad 1989). However, most estimates of negative epistatic effects for MY available in the literature, have been obtained from comparisons of  $F_1$ s and  $F_2$ s in situations where the two are not contemporaneous. In a study in which epistatic effects were estimated from data in which the different crosses were contemporaneous, Mackinnon *et al.* (1996) reported favourable epistatic effect for MY. Of all the traits examined in the present study, except MY and AMY, differences in performance between  $F_1$  and  $F_2$  could be adequately explained by expected heterosis reduction.

Not many studies have examined performance of  $F_3$  and  $F_4$  relative to that of the  $F_1$  population. The present results indicate that there is no reduction in performance in  $F_3$  and  $F_4$  beyond that of  $F_2$ . Thus, continuous *inter se* mating combined with selection can be used to create a composite population with 1/2 exotic inheritance.

**Options for utilising breed resources.** No one breed or crossbreed will have superior aggregate performance in all environments. Combinations of breeds or crosses and production environments are more likely to give optimal results. Cunningham and Syrstad (1987) suggested a pathway for optimising performance through a combination of crossbreeding and

within-breed selection. Where the environment is too stressful for crosses and pure exotics, attention should be given to improvement of pure indigenous breeds. Where exotic crosses perform well, one needs to determine which exotic breed is most economical and what level of exotic inheritance is optimum. If pure exotic is the most appropriate, then a combination of upgrading to exotic and selection within the population is recommended. Crossbreeding (e.g. rotational crossing) in combination with selection within parental population, if feasible, is recommended when intermediate grades are found to be the most appropriate and heterosis is considered important. Unfortunately, the operational complexity of crossbreeding precludes its successful application by smallholders. In such situations, or in the absence of heterosis, an investment in the formation of a composite breed may be worthwhile. However, genetic considerations suggest that rotational crossing would lead to somewhat better dairy performance, mainly because of larger heterosis (Syrstad 1996). Thorpe *et al.* (1993) have suggested that, when stratification is not possible, or when reproductive rates are low, two-breed rotational crossbreeding, when feasible, is an efficient system to exploit additive and nonadditive genetic variation for tropical dairy production.

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