SELECTION FOR MILK PRODUCTION IN THE
INDIGENOUS CATTLE OF THE TROPICS

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Traits of economic importance and their inheritance in the indigenous tropical dairy cattle are reviewed. The different systems of breeding (selection within indigenous cattle, importations of exotic and other tropically adapted breeds, and crossbreeding) and selection methods (pedigree, individual, and family selection) are examined. Methods of sire evaluation are indicated and short notes are made on the developments of three dairy breeds. Finally some general recommendations and conclusions are made.

There is a within-herd variation in milk yield among tropical cattle and the coefficient of variation is known to be twice as high as that of European breeds. Existing evidences show a seasonal sexual activity in tropical breeds but the factors causing it are uncertain. Late age at first claving and long calving interval are reported for these breeds and statistical studies have shown a significant correlation between the two factors, however, they are known to be unrelated or weakly related to yields within lactations. It has been indicated that the $h^2$ of the economically important traits vary according to the condition of the herd the data are derived from. But there is a suggestion that $h^2$ for milk yield in the tropics follows the same pattern as in temperate breeds.

Of the different systems of breeding, crossbreeding with the aim of a new breed formation is indicated as a promising alternative.
1. INTRODUCTION

The majority of cattle in the tropics are very poor milkers due in part to the current levels of management and nutrition and the absence of any practice of selection for ability to produce milk. The introduction of exotic dairy breeds has not always been successful in countries where it has been attempted, except at altitudes which have permitted sophisticated standards of management. Climate, disease and lack of expertise in management have all contributed to the failures. Where a measure of success has been gained, it has sometimes been with production costs which prevent milk from reaching the people who need it most (Hayman, 1970).

Crossbreeding between the indigenous and exotic cattle has been tried in many countries on numerous occasions. The object has been to combine the adaptability of the one with the productivity of the other. Further crossbreeding with segregating generations has, however, seldom been practiced and instead a direct backcross to either one or the other parent has been made with consequent loss of production or hardiness according to the direction of the backcross. This genetically futile approach has sometimes discredited the practice of crossbreeding. In few instances in which selection for production has accompanied a crossbreeding programme, tropical dairy animals like the Jamaica Hope and the Australian Milking Zebu have been evolved.
During the last decades, breeders in several countries of the tropics have attempted to improve the productivity of their indigenous cattle by selection and progeny testing, but the limitations on the improvement in the genetic merit of indigenous tropical breeds must be realised, as it is likely that some characteristics that ensure that these cattle are adapted to their environment adversely affect productivity. As Mahadevan (1966) has stressed, with the exception of a few breeds average milk production of the indigenous tropical cattle is not much higher than 680 kg per lactation and thus their average genetic merit for milk production is low. In addition, the intensity of selection that can be practiced is likely to be low for a variety of reasons including long generation intervals and high mortality. Under these circumstances improvement in the milk production of indigenous cattle by selection is likely to be a very slow process.

The objective of this study is, therefore, to review the general reproductive and lactation performance of the dairy breeds of cattle indigenous to the tropics and to compare and contrast the merits of the different breeding systems, including selection, as measures to improve the milk production of these breeds.
2. REVIEW OF TRAITS OF ECONOMIC IMPORTANCE OF ZEBU CATTLE

The economic traits which have some direct and indirect bearing on milk production:

2.1 Age at first calving

One of the chief reasons for the uneconomic nature of dairying in the tropics is the late age at first calving of animals indigenous to these areas. This appears to be partly a consequence of their late age at first heat. Two studies with Hariana heifers in India found mean ages at first heat of 30 months (Ahuja, Luktuke abd Bhattacharya, 1961) and 42 months (Luktuke and Subramanian, 1961); if the heifers were successfully bred at first heat they would calve at 3 years 3 months and 4 years 3 months respectively. Chaudhry, Shah, Khalil-UR-Rehman and Shah (1983) reported that age at first sexual maturity and at first calving averaged 1.7 and 2.7 years respectively for a herd of Cholistan cattle in Pakistan. This appears to be much lower since tropical cattle are usually over 3½ years of age at first calving. Sundaresan, Eldridge and Atkenson (1954) suggest that late first calving may be regarded as a physiological and probably hereditary trait peculiar to the tropical breeds.

Age at first calving may also be influenced by the number of services per conception. If conception rate at first service is low, this will increase calving age. Luktuke and Subramanian
found that conception rate at first heat was 38% for Hariana heifers and Chaudhury, Lukutke and Sharma (1965) reported 41.4% later for the same herd.

If an early first calving could be achieved with tropical stock, the advantages would be twofold. There would be a decrease in the unproductive period of the cow's life and, therefore, the prospects for cattle husbandry in the tropics would be improved. The interval between generations could also be reduced, thereby making sire testing a more practical proposition. Some early maturity experiments (Sayer, 1936; Mahadevan, 1953) have shown that it should be possible to lower the age at first calving by good feeding and management in early life. However, overfeeding may result in a lower milk yield as for example shown by Little and Kay (1979). The mean age at first calving of some tropical cattle and that of some crosses reported by Mahadevan (1966) is shown in Table 1. The table reveals that irrespective of whether the cattle are Indian, African, European or crossbred, the mean age at first calving of cattle in the tropics generally varies from about three to four years. It would also seem from Table 1 that both purebred Bos taurus and crossbred (Bos taurus x Bos indicus) cattle have an age at first calving in the tropics not significantly different from that of Bos indicus cattle.

The relationship between age at first calving and milk yield has been studied in a number of investigations. Amble and Krishnan (1960); Kohli, Suri, Bhatnagar and Lohia (1961); Alim (1962);
and Puri and Sharma (1965) reported significant linear increases in first lactation milk yield with increase in age at first calving in Kangayam, Hariana, Butana, Tharparkar and Sahiwal cattle. On the other hand, Askar, El-triby and Bedir (1958); Singh and Sinha (1960); Singh and Desai (1961); and Singh and Chaudhury (1961) working with Egyptian, Tharparkar, Hariana, Sahiwal, Tharparkar, Red Sindhi and crossbred cattle respectively, detected no effect of age at first calving on heifers' yields. It would seem, thus, that there are herd rather than breed differences in the influence of age at first calving on lactation milk yield in the tropics.

2.2 Gestation period

The period between two consecutive calvings is referred to as the calving interval. It may be divided into two parts - the period between calving and conception, known as the service period, and the period of gestation. Of these the period of gestation in dairy cattle is usually between 280 and 290 days with standard deviation of about 5 days for individual gestations.

Many studies have been conducted to determine the causes of variation in gestation length in tropical cattle. Prabhu (1961) analysed 9,545 gestations of Indian cows from many herds and breeds and showed a distinct month to month variation in the duration of pregnancy; cows calving in the months of September, October, November and December had shorter gestation than those calving in other months. The effect of season of calving on the duration of
<table>
<thead>
<tr>
<th>Breed</th>
<th>Location</th>
<th>Age at 1st calving (months)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Sindhi</td>
<td>Karnal, India</td>
<td>42.9</td>
<td>India: N.D.R.I., 1961</td>
</tr>
<tr>
<td>Red Sindhi</td>
<td>Hosur and Bangalore, India</td>
<td>41.7</td>
<td>Amble et al., 1958</td>
</tr>
<tr>
<td>Sahiwal</td>
<td>Karnal, India</td>
<td>42.2</td>
<td>India: N.D.R.I., 1961</td>
</tr>
<tr>
<td>Sahiwal</td>
<td>Kanke, India</td>
<td>41.1</td>
<td>Singh and Choudhury, 1961</td>
</tr>
<tr>
<td>Tharparkar</td>
<td>Karnal, India</td>
<td>43.8</td>
<td>India: N.D.R.I., 1961</td>
</tr>
<tr>
<td>Tharparkar</td>
<td>Kanke, India</td>
<td>43.2</td>
<td>Singh and Choudhury, 1961</td>
</tr>
<tr>
<td>Hariana</td>
<td>Mathura, India</td>
<td>46.7</td>
<td>Singh and Desai, 1961</td>
</tr>
<tr>
<td>Hariana</td>
<td>Hisar, India</td>
<td>59.3</td>
<td>Kohli et al., 1961</td>
</tr>
<tr>
<td>Kenana</td>
<td>Wad Medani, Sudan</td>
<td>38.4</td>
<td>Alim, 1960</td>
</tr>
<tr>
<td>Butana</td>
<td>Athara, Sudan</td>
<td>44.0</td>
<td>Alim, 1962</td>
</tr>
<tr>
<td>Native Egyptian</td>
<td>El-Sirw and Gemizah, Egypt</td>
<td>44.3</td>
<td>Asker et al., 1958</td>
</tr>
<tr>
<td>Nganda</td>
<td>Entebbe, Uganda</td>
<td>42.7</td>
<td>Maliadevan and Marples, 1961</td>
</tr>
<tr>
<td>Small E. African Zebu</td>
<td>Western Kenya</td>
<td>42.7</td>
<td>Galukande et al., 1962</td>
</tr>
<tr>
<td>Boran and Jiddu</td>
<td>Tanga, Tanganyika</td>
<td>39.9</td>
<td>Mahadevan and Hutchison, 1964</td>
</tr>
<tr>
<td>Indian x African crossbred</td>
<td>Western Kenya</td>
<td>42.3</td>
<td>Mahadevan et al., 1962</td>
</tr>
<tr>
<td>European x African crossbred</td>
<td>Tanga, Tanganyika</td>
<td>37.4</td>
<td>Mahadevan and Hutchison, 1964</td>
</tr>
<tr>
<td>European</td>
<td>Bopatalawa and Ambawela, Ceylon</td>
<td>40.0</td>
<td>Mahadevan, 1956</td>
</tr>
</tbody>
</table>

**SOURCE:** Mahadevan, 1966
pregnancy was also confirmed by other studies (Hadi, 1966; Rajulu and Rao, 1966; Dymnicki, Osinska, Sobczynska and Jasiorowski, 1983). However, studies made by Singh, Sinha and Singh (1958); Singh and Ray (1961) have shown no effect of season on gestation period. Dave (1950); Mukerji and Ekka (1960); Prabhu, Mukherjee and Chatterjee (1961); and Singh and Ray (1961) attributed the variation in gestation length to the sex of the calf and showed that male calves were carried longer than female calves. This is in disagreement with reports made by Singh, Sinha and Singh (1958); and Singh and Dutt (1961) which detected no effect of sex of calf. Age of the dam has also been indicated as a cause of variation for this trait (Kim, Lee, Baek and Kim, 1982).

Prasad (1958) using 1,338 records from 365 Tharparkar cows found that the mean length of the first post-partum interval to conception was 131 days, with a coefficient of variation of 61%. The post-partum interval was significantly higher after first calving than after subsequent calvings. In another study, Kohli and Suri (1960) reported an average post-partum interval and an interval to fertile service of 230 and 280 days respectively for a herd of Hariana cows. An average of 1.4 services were required per conception and the interval to fertile service following the second calving was the shortest, being 239 days, while the average for all calvings was 268 days. A study made by Biswal and Rao (1960) with Red Sindhi cows has shown the interval between parturition and first oestrus to be 110 days for cows whose calves were weaned and 157 days for those suckling their calves.
The service period in the dairy cow bears the same relation to milk production as does the calving interval. There would be economically no advantage in having high lactation yields if they were associated with long service periods and long calving intervals, as they would only serve to reduce the average daily milk yield, total lifetime production of milk, and the number of calves produced in the lifetime and thus impair the economic value of the cow.

2.3 Calving interval

That service periods and calving intervals can be reduced without any detrimental effects on production was first demonstrated by Sayer (1934) who found that with special feeding and handling the service period in a Sahiwal herd was reduced from 172 days to 90 days. Among improved breeds of tropical cattle such as the Sahiwal, Red Sindhi, Tharparkar and Kenana, calving intervals usually vary from 13 to 18 months depending on management (Amble, Krishnan and Syrivastava, 1958; Alim, 1960; Mudgal and Ray, 1960; Tohar and Taylor, 1967; Ghose, Haque, Rahman, Saadullah, 1979; Patro and Rao, 1983).

Several statistical studies have been conducted on the relationship between milk production, length of calving interval and age at calving. Between cows of the same parity, age at calving and length of preceding calving interval were usually found to be significantly correlated, whereas milk yield within
lactations was either unrelated or only weakly related to these two factors (Singh and Desai, 1961; Turton, 1962).

2.4 Female reproduction

When male animals run freely with breeding females, a detailed knowledge of the specific character of the oestrous cycles of tropical livestock is less important. However, as soon as seasonal breeding, controlled mating or artificial insemination is introduced, a knowledge of such matters is essential. The length of the oestrous cycle and the duration of the oestrus vary greatly from animal to animal within a breed. It has been commonly stated following an early report by Anderson (1943), that the duration of oestrus is much shorter in tropical breeds of cattle than in temperate breeds. Webster and Wilson (1966) have revealed that the chief variable in the reproductive cycle of the female in tropical breeds is the length of the oestrous cycle and suggested that this parameter can be modified by subjecting the animal to some changes in its environments, such as altering the level of feeding.

An examination of the breeding records of tropical cattle shows that the year can be divided into two halves, in one of which 60 per cent or more of the total calf crop is born (Wilson, 1957; Alim, 1960). An analysis of records of 2,469 females of Indian White cattle revealed a significant seasonal sexual activity in non-descript and Kangayam animals while European crossbreds and Sindhi cattle showed no significant
correlation in that respect (Rathnasabapathy, 1958). The mechanisms which operate this seasonal change in the reproductive behaviour are not known with certainty. It may be linked to rainfall distribution which influences grass growth and hence a nutritional factor, or it may be associated with changes in parasitism and animal health which affect reproduction efficiency. Williamson and Payne (1978) suggested that apart from the abnormality of disease, the most important factors affecting the oestral cycle appear to be the plane of nutrition, the length of daylight and ambient temperature.

Whatever the causal factors which operate these patterns, there is a certain amount of evidence that seasonal calving programmes may be beneficial in the tropics when there is not a steady demand for animal products and to make the fullest use of the seasonally available pasture.

Reproductive performance in dairy cattle can be improved by various means. One method is to breed early and thus reduce the age at first calving although this would require considerably improved levels of feeding. A reduction in the length of the calving interval is another way of improving reproductive ability. Longevity has also been suggested as a means of achieving increased reproductive ability. Though the importance of long, healthy and fertile lives for dairy cows is unquestionable, the fact is that if all cows were kept in the herd for as long as possible, the rate of genetic progress would be reduced.
2.5 VARIATION IN MILK PRODUCTION AND THE PROBLEM OF MILK LET-DOWN

From a genetic viewpoint, an interesting feature common to all breeds of tropical dairy cattle is the great within-herd variation in milk yield. Whereas in European cattle the usual coefficient of variation is 20-22%, corresponding coefficients for different cattle populations in the tropics are about twice as high (Manadevan, 1966). As early as 1931, Sikka reported a coefficient of variation in milk yield of 40% for the purebred Sahiwal herds of India in which the mean lactation yield was 1,890 kg of milk. Robertson (1950), using data for White Fulani cattle in Nigeria, whose average first lactation yield was 810 kg, found that the coefficient of variation was close to 50%. High within-herd coefficients of variation for lactation milk yield in Ceylon, India and African cattle with mean yields ranging from about 450 kg to 1,125 kg have also been shown (Mahadevan, 1951; 1955; Mahadevan, Galukande, and Black, 1962). If these variations are largely genetic, the adoption of proper breeding methods should permit rapid gains in milk production in these herds. Unfortunately, there is little to suggest that the increased variation in milk yield in tropical cattle is associated with an increase in heritability but is rather largely linked to increased environmental variability.

Many Zebu cows refuse to let down their milk without the stimulus of the calf suckling and despite persistent efforts to draw milk from such cows, in the absence of their calves little milk is obtained. With temperate cows voluntary ejection of milk
can be effected by using many stimuli other than suckling but for a larger number of tropical cows suckling is the only stimulus that produces a response. It is thus clear that when computing lactation yields, it is impossible to make any satisfactory allowance for the very variable quantity of milk taken by calves. Various corrections ranging from the vaguest allowance to systematic additions to the lactation yield or average daily yield have nevertheless been made in the past. At the Sakrand Farm of Tharparkar cattle in Pakistan (Joshi and Phillips, 1953) the average milk production was 1138.5 kg and it was estimated that a further 450 kg were produced per lactation and consumed by the calf during suckling. In a herd of Boran cattle bred for milk production in Kenya (Faulkner and Brown, 1953) a daily calf allowance of 2.7 kg of milk was added to the total weight actually milked. This resulted in the recorded lactation yields being nearly double the quantity of milk collected in the pail.

The problem of milk let-down, which is a common feature in Zebu cattle, is not universal among them. Generally it would appear that there is less trouble with animals that have a higher inherent potential for milk production. When this problem is prevalent, the usual method of milking cows is to allow the dam to suckle the calf prior to milking. This involves using the calf purely to induce the let-down of milk, removing the calf as soon as milk flow commences, then hand milking as much as possible, and repeating the whole process if necessary until all the milk has been withdrawn.
3. INHERITANCE OF ECONOMIC CHARACTERS

The causes of variation in milk yield and other characters of economic importance in dairy cattle may be divided into two main groups - genetic and environmental. The first group comprises all differences which may be attributed to heredity and the second all the other causes of variation between as well as within individuals. It is not possible to decide whether the variations for a single cow from the average performance of the herd to which it belongs are due to genetic or environmental factors. But with a large number of cows it is possible to estimate by means of appropriate statistical methods, the relative roles of heredity and environment.

3.1 Repeatability

The term repeatability is used principally in the context of those traits of animals that vary in their expression from time to time. The milk yield of a cow, for example, varies from one lactation to another and so do other traits such as length of lactation, length of dry period and calving interval. If the variation is small, that is if the trait is highly repeatable from time to time, a single measurement of the trait will be almost as reliable as the average of several measurements. Under such circumstance culling on the basis of the first record should be effective in improving the overall record of the herd (Lasley, 1978). The stability of milk yield in
different lactations of zebu cows in the tropics was first analysed by Sikka (1933). Using the milk records of Sahiwal cows in India Sikka (1933) correlated the successive lactation yields of a cow with her highest lactation yield standardised to 85 days' service period. The value of the correlation coefficient was found to increase with successive lactation yields, the values being 0.50±0.04 in the first lactation, 0.66±0.03 in the second, 0.67±0.03 in the third and 0.77±0.02 in the fourth. Despite the relatively high correlations, Sikka (1933) concluded that much reliance cannot be placed on any individual lactation yield as a measure of a cow's milking ability and added that there does not appear to be much justification for culling cows on the basis of their first lactation yield alone. In another study, 726 lactation records of 347 Hariana cows at two experimental farms were analysed by Singh and Tomar (1983) and their results showed that repeatability estimates of 150 and 300 day milk yields were significant (0.54±0.02 and 0.37±0.03 respectively) for the 1st-4th lactations.

The moderately high repeatability of milk yield (0.5 to 0.7), when considered in conjunction with Stonaker's (1953) estimate of 0.5 for the repeatability of butterfat yield in succeeding lactations, show that permanent differences between cows, including genetic differences, are present on an adequate scale for improvements in milk and butterfat production to be achieved by adoption of proper breeding methods. On the other hand, selection will not be very effective in improving traits
like calving interval and dry period due to their low repeatability estimates (Mahadevan, 1966).

3.2 Heritability ($h^2$)

Heritability is the fraction of the observed phenotypic variance which results from differences in heredity among the genes and gene combinations of the individual genotypes as a unit (Warwick and Legates, 1979). This is the broad concept of $h^2$ in which the heritability variance is considered as the sum of the additive, the dominance and the epistatic variances. The narrower definition of $h^2$ represents the fraction of the observed phenotypic variance, which is additively genetic or which is associated with differences in average breeding values, is more useful in most aspects of animal improvement.

The $h^2$ of a given trait refers to the particular population in which it was estimated and to the condition under which the population existed and thus it may not be constant and may show a wide range of variation. One of the first essentials in the application of genetics to animal improvement is the determination of $h^2$ that need to be improved. There are several methods of estimating $h^2$, all of which are based essentially on computing the degree of resemblance between related individuals in a random bred population. The method which is most commonly used involves the correlation or regression of offspring on the dam without groups of offspring by the same sire.
Studies of the $h^2$ of milk yield at different environmental levels within temperate countries have yielded rather conflicting results. Johanson (1953) found $h^2$ to be higher in high level Swedish Red and White herds than in low level herds (0.39 vs. 0.32) though the difference was not significant. Korkman (1953) reported $h^2$ values of 0.50, 0.37 and 0.30 from high-, medium-, and low-yielding herds of the same breed. Gravert (1958) also found a similar pattern for first records expressed as deviations from herd averages (0.31, 0.26 and 0.12 for high-, medium-, and low-yielding herds) in Germany. On the other hand, several other analyses (Gravert, 1959; Robertson, O'Connor, Edwards, 1960; Burnside and Rennie; 1961; and Van Vleck and Bradford, 1964) have not shown the same increase in $h^2$ with an increase in production level of herds. The $h^2$ of milk in the tropical cattle is suggested to follow the general pattern of $h^2$ estimates obtained in temperate countries (Alim, 1961; Singh and Desai, 1961; 1962; Mahadevan, 1962; Amble, Krishnan, Sriv Astava, 1958; and Alim, 1962).

Amble and his co-workers (1958, 1960, and 1963) using data from Indian herds of cattle found that $h^2$ was generally highest for lactation yield and varied, with the exception of one herd, from 0.34 to 0.67 for lactation yield. These workers also found that $h^2$ estimates for calving interval were low for all the herds. Their results are shown in Table 2. In two of the herds (the Tharparkar herd at Patna and the Kankrej herd at Anand), there was significant heritable variation in age at
first calving. The summary of $h^2$ of various production traits for East African cattle as estimated by Mahadevan and Marples (1961) and Mahadevan, Galukande and Black (1962) are shown in Table 3. In view of the wide fiducial limits, one can only conclude that there is some evidence that heredity plays some part in determining variations in milk production and certain associated characters in tropical cattle.
TABLE 2. HERITABILITY OF PRODUCTION CHARACTERISTICS IN INDIAN CATTLE

<table>
<thead>
<tr>
<th>Herd</th>
<th>Lactation milk yield</th>
<th>Yield/Day of lactation</th>
<th>Yield/Day of calving intervals</th>
<th>Length of lactation</th>
<th>Length of calving interval</th>
<th>Age at first calving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Sindi (Hosur)</td>
<td>0.34</td>
<td>0.20</td>
<td>0.20</td>
<td>0.04</td>
<td>-0.08</td>
<td>-0.09</td>
</tr>
<tr>
<td>Red Sindi (Bangalore)</td>
<td>0.37</td>
<td>0.54</td>
<td>0.38</td>
<td>0.33</td>
<td>0.13</td>
<td>0.16</td>
</tr>
<tr>
<td>Kangayam (Hosur)</td>
<td>0.58</td>
<td>0.52</td>
<td>0.34</td>
<td>0.13</td>
<td>0.11</td>
<td>-0.08</td>
</tr>
<tr>
<td>Tharparker (Patna)</td>
<td>0.42</td>
<td>0.23</td>
<td>0.11</td>
<td>0.29</td>
<td>0.28</td>
<td>0.44</td>
</tr>
<tr>
<td>GIR (Bangalore)</td>
<td>0.67</td>
<td>0.64</td>
<td>0.91</td>
<td>0.64</td>
<td>-0.37</td>
<td>-1.24</td>
</tr>
<tr>
<td>Kankrej (Anand)</td>
<td>0.13</td>
<td>0.23</td>
<td>-0.54</td>
<td>0.08</td>
<td>-0.31</td>
<td>0.66</td>
</tr>
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### TABLE 3. HERITABILITY OF PRODUCTION CHARACTERISTICS IN EAST AFRICAN CATTLE

<table>
<thead>
<tr>
<th>Traits</th>
<th>Nganda herd Entebbe</th>
<th>Small E.African Zebu herd West Kenya</th>
<th>Sahiwal grade herds West Kenya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight</td>
<td>0.33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12-month weight</td>
<td>0.27</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18-month weight</td>
<td>0.34</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Age at 1st calving</td>
<td>0.08</td>
<td>0.25</td>
<td>0.20</td>
</tr>
<tr>
<td>1st lactation milk yield</td>
<td>0.20</td>
<td>0.50</td>
<td>0.14</td>
</tr>
<tr>
<td>Av. daily milk yield in 1st lactation</td>
<td>0.23</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Highest lactation milk yield</td>
<td>-</td>
<td>0.47</td>
<td>0.34</td>
</tr>
<tr>
<td>Av. milk yield of 1st-4th lactations</td>
<td>-</td>
<td>0.45</td>
<td>0.24</td>
</tr>
<tr>
<td>Length of first lactation</td>
<td>0.11</td>
<td>0.47</td>
<td>0.24</td>
</tr>
<tr>
<td>Length of first calving interval</td>
<td>-0.10</td>
<td>0.00</td>
<td>0.06</td>
</tr>
<tr>
<td>Length of first dry period</td>
<td>-0.53</td>
<td>0.29</td>
<td>0.19</td>
</tr>
</tbody>
</table>

**SOURCE:** Mahadevan and his co-workers (1961, 1962)
4. GENETIC IMPROVEMENT

The two different types of factors that are responsible for the differences between individual animals are environmental factors (due to climate, nutrition, health and management, which may be designated E) and the genetic factor due to the random sampling of genes received from the two parental gametes - the ovum and spermatozoon. These factors act together so that the total variation between two animals is equal to the sum of the effects of all the E and G factors and the interaction between the two, i.e. Total variation = E + G + EG.

Clearly, there is little or no point in attempting to improve livestock by genetic means for a particular character if most of the variation of this character is environmentally determined. Genetic improvement of a trait can only take place if this trait is reasonably highly heritable. It is, therefore, of the utmost importance that the $h^2$ of the various traits in livestock improvement programmes be known in order that breeding programmes could concentrate attention on those of highest $h^2$. Estimates of $h^2$ of economic traits such as milk yield or butterfat percentage vary for different breeds and according to the environmental condition under which the animals in question are kept. Harsh environments give rise to a greater degree of environmental variation and consequently lower estimates of $h^2$ (Wagnon and Rollins, 1959). Nevertheless, the order of ranking of the $h^2$ of different traits is generally fairly similar and factors which are strongly inherited
in *Bos taurus* cattle will also tend to be strongly inherited in *Bos indicus*, even though the actual coefficients may be different in values.

Heritability estimates of traits of economic importance of dairy cattle for Indian breeds have been well reviewed by Sundaresan (1975). Similar attempts have been made for breeds of dairy cattle of the tropics in general by Mahadevan (1966). Sikka (1933) found the correlation between the individual lactation yields of a cow to increase from the heifer lactation ($r = 0.5$) to the fourth lactation ($r = 0.8$) and concluded that estimates of $h^2$ would vary depending on how many lactations were used in the calculations and that there was also little justification in selecting tropical dairy cattle on the basis of heifer lactations. It has also been indicated that unlike the temperate breeds, tropical dairy cattle demonstrate a drop in yield during the second lactation compared with the first instead of a steady increase from first through second to third lactation. This is a further drawback to the selection based on the first lactation milk yield of the cow.

Mahadevan (1955) and Alim (1960) estimated the $h^2$ of milk yield to be of the order of 0.2-0.3 in Zebu cattle in Pakistan, Ceylon, India and Sudan. The same range has been reported by Williamson and Payne (1978) for tropical breeds in general. These results are surprising since they are lower than the general scale of values recorded for temperate cattle and it might be reasonably
expected that the comparatively unselected and heterogenous Bos indicus cattle would provide higher $h^2$ estimates than the comparatively highly selected and homogenous Bos taurus cattle.

It would appear that the greater genetic range in tropical livestock is masked by a greater range in the operation of environmental factors. Where management practice is continuously altering as it does on many government stations in the tropics, the environment is not constant from one generation to another and true assessments of the role played by genetics in livestock improvement are extremely difficult to obtain. As management becomes more uniform and environmental factors (grass quality, general nutrition and health) become more standardised from one generation to the next, it is possible that hidden genetic differences between individuals and breeds will be revealed.

4.1 Systems of breeding

Tropical livestock breeders are often confronted with the question of which breed to improve and which breeding policy to adopt to maximise the rate of improvement in productivity. There is of course no single breeding policy that is applicable in all tropical countries. Hence breeding organisations and farmers may choose one of the following possible alternatives:

4.1.2 Selection from within the indigenous tropical breeds - this approach minimised the disease risks and avoids the problem of acclimatisation required for exotic stock. On the
other hand, the length of time taken to reach the desired goal is often excessive. Sundaresan (1975), for example, reported that for Indian dairy cattle with the $h^2$ of milk yield as low as 0.30 and average production of the selected population around 600 kg of milk per lactation, to increase the average production to 2500 kg, it would need about 25 generations of selection which is in the neighbourhood of 150-200 years on the basis of a genetic gain of about 5.7 per cent in dairy cattle per generation.

Thus in view of the time required to bring about the desired genetic improvement, this method does not appear to be the best alternative.

4.1.3 Importation of high-producing temperate type breeds - the use of pure temperate breeds (exotics) for the improvement of tropical milking cattle has produced variable results depending on principally management levels, type of feedstuffs and the nature of the climate involved. Many governments as well as private producers consider this alternative as the quickest solution to the deficits of milk in the tropics. From the theoretical point of view, it may seem that this method is likely to provide rapid results but the possibility involves high expense and often suffers from major risks in respect to disease and acclimatisation.

The reproductive efficiency, milking performance and survival rates of grade Holsteins imported in advanced pregnancy
from Virginia, USA, to the lowlands of Venezuela, has recently been reviewed (Vaccaro, Cardozo and Vaccaro, 1983). Of all pregnancies, 76.4% resulted in live calves, 12.2% in dead calves, 11.4% in abortions, and retention of the placenta was recorded in 18.7%. 81.3% of the calves died during the 1st year as a result of pneumonia and diarrhoea. Eight of the 98 imported heifers died within the 1st year, having been in a very poor condition. The estimated milk yield per heifer imported was 2,419 kg during the 1st year. European x Zebu heifers on the same farm had produced a mean of 2,496 kg of milk in 244 days. The results obtained in the Venezuela study with respect to calvings, survival and milk production follow the general pattern observed with temperate breed cattle in the tropics (Pearson de Vaccarom 1973; 1984; Wilkins, Pereyra, Ali, Ayda, 1979). The foetal losses reported in this study (Vaccaro et al., 1983) were high in comparison with values obtained for pure- and high grade European cattle earlier in the same country (Rios, Bodisco, Carnevali, Cevallos, 1965). On the other hand, Kurek (1966) recorded a loss of 18.9% through abortions in the 1st year among Friesian heifers imported from Holland to Morocco. While the incidence of retained placenta exceeded that of 5-12% considered normal in temperate zones (McDowell, Velasco, Van Vleck, Johnson, Brandt, Hollon, McDaniel, 1974) it was similar to the rate given by Fenton, Blanco, Ramirez (1976).

All existing evidences support the impracticability of dairy development plans for the tropics (except where the conditions are
conductive) based on the importation of specialised temperate zone breeds under the present conditions.

4.4.4 Importation of tropically adapted cattle from other tropical countries - this policy has the merit of combining many of the advantages of the above mentioned two methods, whilst minimising most of the disadvantages other than probably the cost. It enables certain tropical countries to benefit from the experience of, and advances made in, other tropical regions. A good example of this approach is the importation of Sahiwal cattle from Pakistan to Kenya (Kenya Vet. Dept., 1961 Meyn and Wilkins, 1974). If the dairy breeds developed for tropical conditions, viz. the Jamaica Hope and the Australian Milking Zebu are spread to tropical countries with similar conditions, it is likely that the major problem of adaptation will be minimised.

The major difficulty preventing the widespread adoption of this policy is that most tropical countries are extremely short of improved stock and thus have little or no surplus animals left over for export and are not well organised for semen sales.

4.1.4 Crossbreeding of temperate x tropical livestock and the evolution of stabilised crossbreds - this system is being adopted in many parts of the tropics and the results so far achieved are promising. The main decision which has to be made in order to implement a policy of cross-breeding followed by breed stabilisation concerns the proportion of temperate
and tropical genotypes. Wherever possible, this should be established by experiment or by drawing on the experience of other tropical countries with similar environmental conditions. If this is not done and temperate males are top-crossed to indigenous tropical females continuously, a point will be reached where health and performance decline and where the situation can only be rectified by backcrossing to the tropical sires. This aimless crossbreeding will result in a gradual regression to indigenous type and a fall back to original levels of production (Webster and Wilson, 1966).

Existing evidence tends to be in favour of maintaining the exotic blood level at around 50% if a reasonable performance is to be realised (Amble and Jain, 1967; Sharma, 1977; Chowdhary and Barhat, 1979). This fact has also been observed by the author during personal involvement in a crossbreeding programme in Ethiopia. So far as this policy is concerned, the other question that requires consideration is the type of exotic breed to be utilised in the crossing programme. Again this has to be established experimentally. A genetic study on the Red Sindhi with Friesians and Danish Reds did not detect a significant difference between the two crosses (D'Souza, Bhat, Mukundan, 1979). Similarly in a study made by Yadav and Sharma (1982) on the Hariana crosses with Jersey, Brown Swiss and Holstein-Friesian, the genetic groups did not differ significantly in their performance. Parekh and Touchberry (1981) in their comparative productive performance study that involved Holstein-Friesians and Guernseys as two sire breeds in a crossbreeding
project also found no significant sire breed effects though the Holstein-Friesians tended to be superior in most traits.

4.2 Selection

The principal objective of selection is to change the mean production value of a given population by increasing the frequency of desirable genes and genotypes. There are three kinds of selections that are usually encountered in animal breeding practice: Pedigree selection, individual selection, and family selection.

4.2.1 Pedigree selection - this involves the selection of individuals on the basis of the performance of their ancestors. Pedigree selection is most useful when very little information is available about the individuals themselves either because they are still young and have not yet demonstrated their own performance or because the trait under consideration is sex limited. Pedigree estimates of an individual's genetic constitution can never be as accurate as estimates based on the individual's own performances. This is mainly because the sampling nature of inheritance makes it impossible to know exactly what genes the ancestors transmitted to the individual. Dalton (1981) states that the main danger in pedigree selection is that the harm done by lowering the intensity of individual selection is greater than the good done by making the selection more accurate.
While using this method, the amount of attention that should be paid to each ancestor in the pedigree is an important consideration. This depends on how closely the ancestor is related to the individual, on how well the merits of the ancestor and of the intervening ancestors are known, on how highly the trait under consideration is heritable, and on the magnitude of the environmental correlations between the ancestors and the individual. The more remote is the ancestor in relation to the individual the less emphasis should be placed on information derived from that ancestor.

4.2.2 Individual selection - this consists of choosing breeding stock purely on the basis of their performance and mating the chosen animals at random. It is particularly useful for characters of high \( h^2 \), not limited to sex, and that can be measured in live animals. The result of an analysis of an empirical Monte Carlo Simulation carried out to quantify the possible bias in this method of selection (Ronningen, 1978) showed that there is a tendency to underestimate the genetic gain by 1-3% when both \( h^2 \) and the proportion selected are low. But high \( h^2 \) with a low proportion selected reduced the bias.

In this method of selection an estimate of the Breeding Value (BV) for a given trait is calculated by the following two formulae based on whether a single or lifetime record is used (Dalton, 1981).

1) \( BV = h^2 \) of the trait \( \times \) (individual deviation),

    if a single record is used.
2) $BV = Kh^2 \times (\text{average deviation of the dam's records from her contemporaries})$

where $K = \text{the number of records}$

$h^2 = \text{the heritability of the trait}$

$t = \text{the repeatability of the trait}$

4.2.3 **Family selection** - this is the choice of animals based on the performance of their close collateral relatives. The unit of selection here is a family rather than the individual. The family may be either a group of progeny or a group of sibs - selection by the two groups being termed progeny testing and sib testing respectively. In practice, young males are selected on the basis of the performance of their offspring in progeny testing or of their sisters in sib testing. The latter has a limited use in dairy cattle as the low reproduction rates of cattle make the size of the family too small for effective sib testing.

The effectiveness of the above mentioned different methods of selection varies from trait to trait depending on such factors as the rate of reproduction in the population, the accuracy of the information used in selection and the age of the animals when the information becomes available. In some circumstances they may be used together with early selection based on pedigrees and later selection on individual performance and on the performance of collateral relatives.
4.3 **Expected genetic progress**

Three important components in estimating genetic gain are \( h^2 \), selection differential (\( s \)) and generation interval. These are put together to give the estimate as follows:

\[
\text{Gain per generation} = h^2 \times s \\
\text{Gain per year} = \frac{h^2 \times s}{\text{generation interval (years)}} \\
= \frac{h^2 \times s \times \text{phenotypic standard deviation}}{\text{generation interval (in years)}}
\]

Maximum gain is obtained from a high \( h^2 \), large selection differential and short generation interval. Two major factors influencing the magnitude of selection differential are reproductive rate and wastage rate. Improved reproductive rate would automatically permit a higher culling rate. In like manner, a lower wastage rate through management and more effective disease control measures would permit a higher selection intensity.

An important limitation to selection progress in cattle in the tropics is the generation interval. The mean generation length for tropical cattle is 6 to 6½ years as opposed to 4 to 4½ years for European dairy cattle (Mahadevan, 1966). This is largely on account of a later age at first calving and longer calving interval. This means that rates of progress from selection will be slow in the tropics. Rate of genetic progress is also dependent on whether the
breeder tries to select for several traits simultaneously. The greater the number of characters involved in the selection programme, the less intense will the selection be for any one character. Selection should therefore be directed towards the most important characters only and traits that have no economic value should be excluded from consideration.

4.4 Breeding for disease resistance

There is no doubt that disease is one of the major limiting factors to livestock improvement in the tropics.

One important consideration is whether any variation exists between individuals and breeds in their resistance to diseases and if so, whether there is any genetic basis for this variation. That variation in resistance to disease does exist has been observed in many studies but in most cases little is known of the factors affecting such variation. Alrawi, Laben, and Pollak (1979) have reported heritabilities of a cumulative score of 0.48±0.07, 0.36±0.08, 0.46±0.15, and 0.23±0.12 for 1st, 2nd, 3rd and 4th lactation groups respectively, and indicated that selection should reduce the occurrence of elevated test scores, in mastitis. Murray, Morrison, Murray, Clifford and Trail (1979) in their review of trypanotolerance have concluded that both epidemiological and experimental evidences exist to confirm trypanotolerance. It was also suggested that it has a genetic basis although this may be supplemented by repeated exposure to the same population of trypanosomes. A comparative study for susceptibility to Anaplasmosis between Herefords, Shorthorns, and Brahman crosses showed no significant difference in their
resistance (Wilson, Parker, Trueman, 1980). In a similar study with Herefords, Droughtmasters and Brahmans for susceptibility to Babesia, however, the latter exhibited significantly higher resistance than the first two breeds (Johnston, Sinclair, 1979). That Zebus are more resistant to trichostrongylosis, gastrointestinal and respiratory diseases and piroplasmosis than either their crosses or purebreds in Russia has also been confirmed by Rcheulishvili, Dolmazashvili and Varazanashvili (1980).

Once a genetic basis for disease resistance is established, the next step is to determine the possible effects of selection for resistance to disease on other economic traits. Certainly, the progress in genetic gain in these traits will be reduced when selection for disease resistance is included. The question is, thus, whether breeding for disease resistance or environmental control of disease is the more practical solution. Where effective therapeutic and curative measures are available against animal diseases, it will mean a deliberate lowering of the intensity of selection for production if disease resistance is included as an additional criteria of selection in the breeding programme.
5. METHODS OF SIRE EVALUATION

5.1 Daughter-dam comparisons

The early methods of sire ovulation involved comparisons of the performance of the daughters of a sire with that of their dams. This is now an outdated method due to limits to its usefulness.

5.2 Simple daughter averages

Artificial insemination has made the use of several sires, each in a wide variety of herds, possible. If the daughters of the sires are fairly distributed in these herds the average environment of the daughters of each sire is unlikely to differ markedly and comparisons may reasonably be placed upon daughter averages. In practice, however, a proportional distribution of the daughters of the several sires in each of the different herds is rarely possible under conditions of nominated mating. In these circumstances, there may well be a preponderance of the progeny of one sire in one herd. Similarities in the management of members of the same progeny group may then lead to differences between progeny groups that have nothing to do with the breeding values of the sires. This means that with traits of low to moderate $h^2$, it is impossible in comparison of the simple average performance of progeny groups to separate the effects of sires from those of the different management levels in different herds.
5.3 Contemporary comparisons

Here comparisons are made between daughters of sires milking in the same herds in the same year. This method is assumed to overcome the shortcomings of the two methods mentioned above. It involves deriving for each sire a series of within-herd-year differences in first lactation milk yield between its daughters and other heifers and the weighted differences from the separate herd-years are then combined into a single average which is the contemporary comparison for the sire in question. A further elaboration of the contemporary comparison method has been developed which is known as BLUP (Best Unbiased Linear Prediction) (Henderson and Quaas, 1976; Henderson, Slanger, Jensen, Everett, 1976; Henderson, 1977).

In progeny testing by the contemporary method, there is a suggestion that only lactation records up to 350 days should be used. An early assessment of the breeding value of a bull might, however, be made by using part records up to either ten weeks or six months of lactation instead of waiting for complete 305-day yields. In a study made by Rao and Sundaresan (1980), a 300-day milk yield was estimated for Sahiwal, Brown Swiss x Sahiwal, and Friesian x Sahiwal, from part-lactation yields of 13, 17, 21, 26 and 30 weeks by regression and ratios. The correlations between the part records and 300-day milk yield ranged from 0.76 to 0.95 (P<0.01), the correlations being highest for Friesian crossbreds. The part records \( \geq 17 \) weeks extended by ratio or regression were said to be
as accurate as a 300 day milk yield when the progeny group size was increased by 7-10% for Sahiwal and 20% for the crossbreds.

It would also be advisable not only from the point of view of an early progeny test but also to overcome the need for age corrections, to use only the first lactation records.

5.4 **Test station comparisons**

This involves the collection of a random group of daughters per bull (usually 18 to 20 daughters) and a study of their performance in the first lactation under the standard environment of a test station. The higher the number of daughters the more accurate the breeding value estimate will be. This has been shown by a study (Klautschek and Mosenthin, 1979) in which bulls tested with 10 daughters were re-tested with 20 and 30 daughters and where the accuracy of breeding value estimation increased from 0.34 to 0.61 for milk yield, from 0.59 to 0.81 for fat percentage and from 0.44 to 0.71 for fat yield.

The decision as to whether the contemporary comparison method in farmer herds or the test station method should be used for the progeny testing of dairy sires will depend on how precisely the production of future daughters in farmer herds can be predicted by each of these methods. Robertson and Mason (1956) compared the predictive value of test station results with those of contemporary comparisons in farmer herds and found that the repeatability of station tests in farmer herds is not high and that the variation
between sires in milk yield is much greater at the test station than in farmer herds. Touchberry, Rottensten and Anderson (1960) after comparing the two systems, however, concluded that for milk production, the tests in farmer herds were superior to those at test stations in all cases except when the number of daughters comprising the test was fifteen or less.

The problems with progeny testing as a method of cattle improvement in dairying and an alternative method of overcoming the drawbacks of this method has well been reviewed by Hinks (1983a;b). This worker recommends what is termed 'a group breeding scheme' in which all the effective breeding and selection activities are concentrated within the elite central nucleus, where the potential mothers of bulls are located. This recommendation particularly seems appropriate to the tropics where field tests are not readily possible due to the low levels of milk recording and thus the test station method of sire evaluation will usually have to be used.

The new technology of embryo transfer may also be used for dairy cattle improvement. Nicholas and Smith (1983) examined possibilities for increased rates of genetic change in dairy cattle through embryo transfer and embryo splitting, using the Multiple Ovulation and Embryo Transfer (MOET) systems, and showed that though selection was less accurate than in conventional progeny testing, the annual rate of genetic improvement could be increased and even doubled. It was also indicated that a scheme with 1 024 transfers per year and 512 females milk-recorded per year would sustain a
rate of genetic improvement about 30% above that possible by a conventional national progeny testing programme. Nevertheless, this method has no immediate application in the tropics due to the techniques involved.

5.5 Genetic - environmental interactions

These may be defined as the differential response of a specific genotype in different environments (Williamson and Payne, 1978). If genetic-environment interactions exist in milk production, selection for this trait under optimum environmental conditions might well produce a strain of animals which are poor producers in other environments because the genetic factors that control production in one environment may be different from those that control it in another.

Several investigations have been made to study the influence of environment on the performance of different traits in cattle. In Australia Friesian bulls were used at random to inseminate approximately 500 cows in 4 Friesian herds. In a preliminary analysis of the results, the breeding values of 4 UK Milk Marketing Board (MMB) bulls, 6 New Zealand Dairy Board (NZDB) bulls, and 3 bulls from the AI centre at Berry in New South Wales (NSW) bulls were estimated from 40 100 and 37 daughters respectively (Brown, Nicholas and Moran, 1981). Estimated breeding values were obtained for milk and fat yields, as regressed least-squares estimates of sire effects, after fitting herd-year-season and age.
The breeding value for each sire is then compared with its published breeding value estimated from daughters in the country of origin of that sire. These results indicated substantial sire x environment interaction for MMB and NZDB sires. In a study made by Van Vleck and Barr (1963) in an attempt to account for the environmental effects among genetic groups, the milk production records of Holstein cows were divided into 39 1st lactation sire groups and 44 2nd lactation sire groups and the variance was estimated for each sire group. The results indicated that the environmental variance is not similar from one genetic group to another and that the sire genotype influences variance of both 1st and 2nd lactation records. Other similar studies made under two levels of environments (low and high based on the milk yields of the animals studied), revealed that genetic variability is evidently different from one level to another and that the higher the level, the more genetic variability (Brumby, 1961; Van Vleck, 1963; Vos, 1964). Interaction between genotype and environment may be studied by the method of genetic correlation if only two different environments are considered and performance in the two environments is regarded as two different characters and the genetic correlation between them is measured (Falconer, 1952).

Experiments such as these if conducted over a wide enough range of environments and with sufficient numbers of animals, should provide evidence on whether separate breeds are necessary for every separate environment in the tropics, or whether one or a few
breeds can reasonably do well for all tropical and subtropical environments which seems the more likely outcome.
6. SHORT NOTES ON ATTEMPTS MADE TO DEVELOP TROPICAL DAIRY BREEDS

Three tropical dairy breeds, viz. the Jamaica Hope (JH), the Australian Milking Zebu (AMZ) and the Dairy Criollo are examined.

6.1 The development of the Jamaica Hope (JH)

The work of the evolution of the breed of dairy cattle now known as the JH may be divided into three phases.

The 1st phase which began in 1910, involved the testing of European breeds and their grades (Jersey, Guernsey, Holstein, Red Poll, Ayrshire and Brown Swiss) in the tropical environment of the Island. The breeding policy at that time was grading-up the native cattle and maintaining purebred herds to produce bulls for improving the dairy cattle of the Island. By 1917 the necessity for maintaining heat-tolerance in the grades was realised and two Sahiwal bulls were imported in 1919 from India for this purpose. Only one bull was used as the other was found to be infertile. On account of the lower age at 1st calving, shorter calving interval and a smaller body size, the grade Jerseys seemed to provide evidence that under conditions in Jamaica they would be more economical milk producers than the other breeds studied. By 1943, it became obvious that the system of breeding through grading-up with Jersey and then crossing with the Zebu bulls to maintain heat tolerence hampered a continued improvement through
selection. The study of the results obtained indicated that to develop a new breed the greatest possibilities lay with the selection within the grade Jerseys having genes for adaptation which they had from the Zebu. Thus the 2nd phase started in 1943 with foundation cattle composed of 26 purebred and 139 grade Jersey females, with an estimated gene pool of 70-75% from Jersey and 20% from Sahiwal. When the development of the JH as a breed started in 1952 the third phase began.

The average yield of the Jamaica Hope recorded in 1955 was 3 579 kg of milk and 177.3 kg of butterfat (Jamaica Dept. Agric., 1957). It is shown in this report that of 64 cows completing lactations of 270 to 305 days, 26.5% exceeded 4 545.5 kg and one cow gave 8 572.7 kg of milk. An earlier report of the same department (Jamaica Dept. Agric., 1954), however, shows an average production of 1 801 kg with a maximum yield of 4 092.3 kg for the breed, though this was recorded in private herds. The $h^2$ of milk yield, age at first calving and calving interval of the JH have been reviewed by Lecky (1962) and the results showed that this breed was better than either the grade-or purebred Jerseys in all the traits except calving interval for the grade Jerseys. This is an indication of a better adaptability of the breed to the local conditions than the two breeds. The development of the JH has been hindered by the milk recording, sire evaluation and AI programmes operating at a lower level of effectiveness than required for satisfactory improvement of the herd.
5.2 The development of the Australian Milking Zebu (AMZ)

Australia originally had no indigenous cattle and the first cattle introduced were *Bos taurus* brought in with the European settlers (Hayman, 1974). As dairy animals, these did not perform as expected in the tropical areas of the country and it was decided to make an attempt to improve their performance by introducing exotic (*Bos indicus*) genetic material and by crossbreeding combined with selection among the filial generations to establish a new breed which would combine the hardiness and resistance to parasites of *Bos indicus* with the higher milking potential of *Bos taurus*. The Red Sindhi and the Sahiwal were used as *Bos indicus* parent genotype and Jerseys as the *Bos taurus* parent genotype. Similar to that of the JH, the development of the AMZ has followed 3 stages.

The 1st stage involved the production of the filial generations and their inter se mating up to $F_3$. All females in each generation were milked for at least their 1st lactation and males for breeding were selected on the basis of their dam's performance. This stage showed the Sahiwal crosses to be superior and the later programme concentrated on animals derived from them. Seventy percent of the filial generations exhibited a failure to let down milk without the stimulus of the calf and were culled. With respect to production, the best crossbred ($F_2$ Sahiwal) produced 4 649 kg of milk and 243 kg of butterfat in 305 days during the 1st lactation which compares with a first lactation of 4 536 kg of milk and 242 kg of butterfat in 205 days from the best Jerseys (Hayman, 1974). Selection was against
poor dairy temperament as well as for production.

The 2nd stage of the breeding programme was based on the progeny testing of young bulls from dams of the required merit. In the later years of stage 1, the herds of the cooperating dairy farmers were used to test bulls born in excess of the station testing capacity. The objective in stage 2 was to progeny test six bulls per year and as selected proven sires became available from the test, the best in each year would be mated with the top 10% producers in each of the cooperating herds in order to produce young sires for future progeny testing. Two screening tests were employed, one to artificial climatic stress and the other to infestation with cattle tick. The bulls surviving the first screening are artificially infested with tick larval and then subsequently challenged with further infestations.

In the 3rd stage only sons of sires selected for their own high production are being submitted to screening and progeny testing. The final object of the exercise is the development of a dairy breed containing between 3/8 and 1/2 **Bos indicus** blood, and selected for milk production, tolerance to hot climatic stress and resistance to ticks. The breed is said to have achieved a satisfactory level of performance in the area for which it was developed.

6.3 **THE CRIOLLO BREED**

This may be described as the dairy breed of tropical Latin
American although it occurs in other regions as well. The breed is the descendant of cattle that were imported from Spain more than 400 years ago (Williamson and Payne, 1978).

The progress in the selection of the dairy Criollo has been reviewed by de Alba (1978). According to this report the most important result of the establishment of these herds was their high fertility. For some years the herd at Turrialba maintained a record of 1.4 services per conception. While this was not maintained in later years, high fertility has continued to be one of the outstanding qualities of the breed. This has proved most valuable as low fertility has been one of the major deterrents to the progress of European dairy breeds in the tropics. Another analysis of data on 440 Criollo cows in 6 herds in Mexico in 1976 and 1977 has shown an overall conception rate of 72.11 and 81.73% and 2.3 and 2.0 services per conception respectively (Alverado Ronguillo, 1979). On the other hand, poorer dairy temperament and milk yield, difficult milk let-down and short lactations were identified as the major problems of this breed.

6.4 Lessons to be learned from the development of the JH, AMZ and dairy Criollo

In the initial stage of breed formation, it is important that the population size should be large enough to restrict inbreeding to levels unlikely to affect performance adversely and to reduce the amount of genetic variation in economic traits. Particularly the programmes of the development of the JH and AMZ
have suffered from a loss of a good number of animals due to inbreeding depression as the foundation stock in general, and from the *Bos indicus* parent side in particular, was small in size. The progeny testing has also been carried out at a very slow rate due to the same problem. Another aspect of these programmes worth noting was the emphasis placed on factors like breed uniformity in colour and heat tolerance. Colour uniformity is not that important so far as it does not interfere with the production ability of the breed. Likewise, if the programme concentrates on selection for milk yield alone, this will indirectly involve selection for adaptability to climate as well since the ones to produce better yields are likely those better adapted. Similarly ability of cows to let down their milk without presence of the calf will also be reflected in milk yield. Therefore, the inclusion of such factors in the programme may only serve to slow down the genetic progress.
7. GENERAL RECOMMENDATIONS AND CONCLUSIONS

7.1 Improved management

Increased production will result from an improved management of animals suited to the local conditions. As standards of management are raised, the quality of cattle can be improved which in practice means a greater amount of Bos taurus blood and less of the Bos indicus. An indigenous herd of cattle in the tropics is the result of natural selection over generations with little influence from the owner. The genetic make up of the herd is in harmony with the environment. The cattle can survive or maintain their numbers under the local conditions where the Bos taurus type breeds would not even survive.

Production of milk by unimproved herds is at present generally limited more by management rather than genetics. There are variations between animals and a certain amount of improvement can be achieved by selection but a more striking response is more rapidly achieved by better management. Moreover, improved animals resulting from either selection or grading-up can only perform well under the appropriate management practices.

As tropical forage varies widely in quality it is difficult to establish basic feeding standards of dairy cattle. In the wet tropics high-producing cows may have some difficulty in obtaining a sufficient quantity of total dry matter because of the low dry matter content of the forage, and it is generally accepted...
that for the major part of the year they are more likely to have
difficulty in obtaining a sufficient supply of energy than
crude protein. It may be assumed, however, that well-managed
pasture in the wet tropics will provide for the maintenance requirements
of milking cows and for the production of 4.5 kg of milk. Cows
that produce more than this level will normally require a concentrate
supplement. In the semi-arid tropics, it is likely that pastures
will provide only maintenance requirements for part of the year
and for maintenance and some part of the milk production during
the wet season, unless irrigation is available. At all other
times the requirements will have to be provided by conserved forage
possibly supplemented with molasses-urea-mineral liquid feed.

In general, if improved breeds are to realise the anticipated
production performance, a corresponding improved management
practices including, housing, the provision of shade in grazing
areas, better feeding, greater attention to calf rearing, provision
of mineral licks, salts and protein sources, better watering
and disease control measures, are essential.

7.2 Improvement of milk recording practices

Milk recording practice in the tropics is established
mainly on government-owned experimental farms and in a few privately
owned herds. It has come to be recognised that milk records
are of value not only to the recording members but also to
the industry as a whole if decisions on dairy cattle breeding in
the tropics are to be of much value. Basically they have two main objectives, i.e. to help the individual farmer produce milk more efficiently and more economically and to produce data for government administrative, research, breeding and extension purposes. Both objectives are of course equally important, but it should be recognised that if the individual farmer can not be convinced that he has something to gain from the practice, it is very difficult to develop extensive recording systems. One should, therefore, avoid overemphasising the national benefits alone, because farmers will believe that recording serves only the interests of the various official bodies.

Although accurate daily recording over the entire lactation might be regarded as the ideal practice in milk recording, the high repeatability of daily milk yields and the high genetic correlations between part and whole lactations suggest that few records spread over the first five months of each lactation will probably give all the information that is required. This is an important consideration in the tropics from the point of view of the scarce resources available that limits recording of entire lactations. Another important aspect is the type of records that should be maintained. Alongside with milk yield, factors like age at first calving, breeding efficiency and dry period are worth considering to bring about an overall improvement.

One of the weakest points of many schemes is that milk recording is carried out more or less divorced from other related
activities. It should be integrated closely with those of the AI organisation, the extension services and the research institutions.

7.3 Marketing of dairy products

The intensity of milk production throughout the tropical world is, with a few exceptions, very low compared with the highly developed dairy areas of the temperate zones. Production is lower per animal and per unit area of land. Roads are usually few and often impassable during seasons of adverse weather, thus inhibiting rapid and economic collection of milk. Refrigeration facilities are generally unavailable in tropical rural areas. Atmospheric and ground water temperatures are relatively high in most areas so that milk may not be cooled promptly, if at all, without mechanical aids. These and other factors, such as traditional standards of sanitation, result in relatively expensive milk, much of it of poor quality.

Some producers supply their milk directly to private consumers. Others sell by contract to milk vendors who own one or two cans and a bicycle, take delivery of the milk at the producer's house and sell it to private consumers. Alternatively, producers may deliver their milk to a point within their own or near by village where milk is bulked. As larger processing operations come into existence, the bulked milk may be chilled at this point in the collection channel or be processed into other products. This latter system has not yet been sufficiently adopted
in the tropics with probably very few exceptions (e.g. India and Kenya). An increased production of milk through an improved breeding system presupposes an efficient marketing and proper pricing policies and thus the experiences of countries like India in this regard should be adopted by other tropical countries with less developed dairy product marketing system.

7.4 Artificial insemination

Very few herds in the areas of intensive agriculture in the tropics are large enough to permit effective progeny testing without some form of co-operative effort between herds. It is in this context that AI has a particularly important role to play. It provides the means whereby a large number of daughters can be bred from a bull and milk recorded in the shortest possible time to assess its merit. AI does not only make a substantial contribution to animal improvement in the tropics through the use of imported semen from the temperate breeds for crossbreeding, but has also a potential genetic advantage in that it allows a larger selection differential when only small numbers of bulls need to be selected for mating with large population of cows.

AI is not merely a method of reproduction or of preventing the spread of infectious diseases; it is a valuable tool in livestock improvement. Nevertheless, it must be recognised that it has its limitations. Equipping and maintaining an AI service, low level of record keeping, the communal land grazing system and the presence of
inferior non-castrated males, the silent oestrus prevalent in Zebu cattle, and the lack of adequate skilled technicians, are some of the potential problems one is likely to encounter in the tropics with respect to this practice. AI is certainly one of the most promising methods of speeding up progress in livestock breeding, but the process must be carried out skilfully, proper techniques must be employed in the selection of sires, the facilities for such selection should be created, and the kind of environment necessary for the genes of superior performance to manifest themselves must also be provided. Then and only then, can an AI service be regarded as a worthy venture in improving dairy cattle production in the tropics.

In conclusion, though it is believed that there exists a variation in reproduction and production performance among the cattle in the tropics and that this implies the possibility of improvement through selection, available evidence does not favour this method. This is on account of two points - first these breeds are potentially poor producers of milk in general and secondly the time required to bring about effective genetic change in the population is immense. An alternative policy is, hence, to cross the indigenous (B. indicus) with the oxotic (B. taurus) breeds followed by selection to evolve a breed that will suit the particular conditions of the country under question. The lead taken by Jamaica and Australia in this regard has to be given due consideration by other tropical countries.
The level of exotic blood to be incorporated into a new breed varies with the prevailing level of management, the situation being that a higher level in the latter will allow a corresponding increase in the former. Under most of the tropical conditions at present, however, a breed with an exotic genotype between 1/2 and 5/8 seems the level to be recommended. Under all conditions, nevertheless, the up-grading of management in animal production and health is as important as the genetic improvement if not more.
REFERENCES


