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Cross-breeding in Cattle for Milk Production: Achievements, Challenges and Opportunities in India-A Review

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Abstract

This paper reviews experiences with cross-breeding for milk production in India. Data were compiled from different studies evaluating the performance of different grades of cross-bred animals as well as local breeds. Relative performance of indigenous breeds compared with different grades of cross-breeds was calculated. Traits considered were milk yield per lactation, age at first calving, services per conception, lifetime milk yield and total number of lactations completed. Exotic inheritance of around 50% is the most ideal for growth, reproduction and milk production, and the yield in higher crosses falls short of theoretical expectations. The grading up, therefore, to a total replacement of genes will not lead to higher production in cattle. The crosses of temperate with improved indigenous breeds (Sahiwal, Red Sindhi, Gir, Tharparkar) attained the same level of performance under uniform feeding and are superior to crosses from other native cattle. Holstein crosses were superior to other temperate breed crosses for growth and production while Jersey crosses have better reproductive efficiency. Decline in milk yield from F_1 to F_2 generations on account of inter se mating among F_1 crossbreds is small. The Friesian crossbreds excelled in milk yield, but were slightly older at first calving and had slightly longer calving intervals than Jersey crosses. A serious decline in performance from F_1 to F_2 was observed in both crosses: F_2 were about eight months older at first calving and produced about 30% less milk. They had also much longer calving intervals. The combination of ART with advanced molecular genetics plus the availability of simple recording schemes provide great opportunities for developing and multiplying synthetic breeds at a much faster rate than in previously conducted breeding programmes. Although cross-breeding faces a number of challenges such as better infrastructure, higher demand for health care, there are many advantages of using it. These are higher production per animal, higher income for the families and provision of high-value food. It is therefore likely to continue to be an important livestock improvement tool in the tropics in the future, where farmers can provide sufficient management for maintaining animals with higher input requirements and access to the milk market can be secured.

Keywords: Crossbreeding; Sahiwal; Holestian; Jersey; Friswal

Introduction

Crossbreeding with improved Bos taurus breeds in India is not new. It has gone on for nearly one century. CAR sanctioned a large crossbreeding scheme in 1955 for hilly and heavy rainfall areas for determining the optimum proportion of exotic inheritance in crossbreds which could sustain productivity after interbreeding under village conditions. The exotic breed used was Jersey. A number of bilateral aided projects like Indo-Swiss Project in Kerala and Punjab using Brown Swiss bulls on local cows, Indo-Danish Project in Karnataka using Red Dane bulls on Red Sindhi cows and Indo-German project in Himachal Pradesh for performance recoding under field conditions were also initiated during sixties and seventies. Based on the initial results of these bilateral projects, the work on performance recording of crossbreds under field conditions was initiated by the National Dairy Development Board under Operation Flood and a number of other organizations like BAIF.

With the advent of artificial insemination and the limited introduction of cross breeding (1961) in the hill areas by the government of India, official policy started recognising cross breeding of cattle with European donor breeds, as a possible option for improving milk production. Several on-farm bilateral cross breeding projects in collaboration with external agencies (UNDP Project in Haringhatta, West Bengal; Indo-Danish Project in Hasserghatta, Karnataka; Indo-Swiss Project in Mattupatty, Kerala and the Indo-German Project in Mandi, Himachal Pradesh) were established in the early sixties, to study the potential of the strategy and to quickly evaluate its impact on milk production and sustainability, under Indian conditions. Cross breeding of non-descript Indian cattle on field scale started in 1964 with the launch of the intensive cattle development projects (ICDP) of the government of India and by 1969 it became the official policy of the government for increasing milk production.

As a result of these efforts, India occupies the first position globally with its annual milk production of million tonnes with an increment of 4%. According to an estimate India's milk production would be 170 million tons by 2020. India has 199.10 million cattle (livestock census 2007) of which there are 72.7 million breed able females including 16.1 million crossbreeds. There are 33.1 million crossbred cattle of which 16.1 million are breed able females. About 72.7 million cows produce 44 million tons of milk (40% of total 110 million tons) out of 40% of total milk produced by cows, 21% is produced by indigenous cows (56.6 million breed able cows) and 19% by crossbred cows (16.1 million breed able cows). It is obvious that about 22.1% of breed able crossbred cattle on producing nearly 48% of total cow milk.

The crossbreeding of non-descript zebu cows with semen of exotic dairy cattle breeds has resulted in enhancing milk production by 5 to 8 times to that of nondescript cows, reducing age at first calving and shortening calving intervals in first generation crossbred progenies. However, in the absence of clear-cut breeding plans and programmes, further breeding of F_1 progeny has resulted in subsequent generations of F_2 and beyond in F_2 generations the advantages observed in the F_1 generation have markedly deteriorated Wakchaure et al. [1].

The technical program for crossbreeding approved by the governments was to use nondescript cattle as the foundation stock and to breed them using semen from exotic donor breeds. This would produce half breeds with equal inheritance from the two widely different parents, one contributing endurance and the other the much needed higher productivity. The policy thereafter was to breed the half breeds among themselves inter se in subsequent generations to maintain the share of inheritance halfway between the Indian and the exotic parents. Genetic progress in the intermating populations would be maintained and promoted through use of genetically evaluation half bred sires for the inter se mating. The exotic donor breeds initially used were Jersey, Brown Swiss, Red Dane and Holstein Friesian. The choice of the exotic donor has now narrowed down to Jersey and Holstein Friesian with Holstein predominating by popular choice.

A comprehensive review of the problems and prospects of cross breeding as a strategy for milk production enhancement in India, or of the strategy's continued relevance, has not been carried out so far, even though the country now has considerable experience on both the advantages and problems of cross bred across a widely different geographical and social strata.

The government did not plan to crossbreed pure Indian breeds of cattle but the spectacular increase in milk yield in the crossbred progenies generated over whelming demand for such cattle all over India. This necessitated the expansion of the crossbreeding program nationwide even to the home tracts of pure Indian breeds. In this review an attempt is made.

- To summarize the findings of several workers & reviewer of the subject over the last 50 years.
- To examine some of the more important work published subsequently to these reviews on crossbreeding of dairy cattle.
- To find out new breeds or types for cross bred foundations.
- To find out a suitable inheritance for higher milk production in Indian conditions.
- To find out suitable inheritance for grade up the local non-descript animals.

Cross-breeding: the genetic back ground and types of cross-breeding

The genetic basis of cross-breeding can be broadly divided into two components: additive and non-additive. The additive component is because of the average effect of the strains involved (breeds or parental lines), weighted according to the level of each parental breed in the cross-bred genotype. Then on-additive component of cross-breeding is heterosis [2]. Heterosis is defined as the difference between the increase in cross-breeds' performance from the additive component based on the mean performance of the pure-bred parental lines. The levels of heterosis are presented as percentage values and can be used to calculate the expected performance of cross-bred individuals [3]. Heterosis is caused by dominance (interactions with in loci) and epistasis (interactions between loci) effects of genes. The positive effects of dominance are the result of increased levels of heterozygosity, which allow an individual to react to environmental challenges in different ways [2]. Epistasis interactions can have a negative effect because of a breakdown of favourable interactions between loci in pure-bred animals, which prior to crossbreeding developed by both natural and artificial selection within breeds [4]. These effects have been observed in cross-breeding studies for milk production in the tropics.

The pioneering work on large scale cross breeding in different parts of India by the Bharathiya Agro-Industries Foundation (BAIF) [5] all through the seventies, validated the positive impact of cross breeding on milk production; and the unequivocal recommendation of the National Commission on Agriculture (NCA) [6] in 1974 that cross breeding should be a major strategy for increasing milk production in India, laid all adverse criticism to rest and legitimised cross breeding as a powerful tool to rapidly enhance milk production. Cross breeding gained momentum and economic relevance in the mid-seventies, as the extensive dairy cooperative network under Operation Flood, moved in to provide the market stimulus and the much needed price support for milk.

The technical programme for cross breeding prescribed by the government of India targeted the nondescript cattle as the foundation stock, to breed them with exotic donor breeds once, to produce half-bred: with equal inheritance from the two widely different parents, one contributing endurance and the other, the much needed higher productivity. The policy thereafter, was to breed the half-bred progenies among themselves inter se in subsequent generations, to create large inter mating populations of half-bred, perpetually maintaining the share of inheritance half way between the Indian and the Exotic parents. Genetic progress in the inter mating populations was to be maintained and promoted through use of genetically evaluated half bred sires for the inter se mating. The exotic donor breeds used initially were Jersey, Brown Swiss, Red Dane and Holstein Friesian. The choice of the exotic donor has now narrowed down to Jersey and Holstein - with Holstein pre dominating the market by popular choice. The governments had no intention to crossbreed pure Indian breeds of cattle. But in actual practice, the spectacular increases in milk yields in the cross bred progenies generated overwhelming demand for crossbred cattle from the farming community almost all over India and necessitated the expansion of the programme nationwide - even to the home tracts of the pure Indian breeds. While most states had been totally indifferent in managing the breeding policy as prescribed and while no attempt was made by most states to produce proven half-bred bulls, Kerala followed the policy strictly and used progeny tested cross-bred bulls for inter se mating, with commendable achievements (Sunandini: a new breed of over a million high yielding cattle). Punjab had completely deviated from the central prescription and had followed a policy of its own, for progressive grading up of the local cattle with Holsteins, taking into account the quality of farmers in Punjab and the resources available in the state. Several years of implementing this policy have endowed Punjab with a highly productive population of cross bred cattle, closer to the Holstein both in production traits and in appearance. In the absence of evaluated half bred bulls, inter se mating in many states ran into disrepute, as progenies in successive generations were reported to be producing yields far below the expected levels and by the nineties, the whole of the crossbreeding programme came to be regarded by many as a very expensive misadventure, unsuitable to the farming systems in the country and causing enormous health and management problems to the small holder producers.

Grading up of cattle in colonial areas with breeds from Europe, such as short horn, Red poll and Jersey, was popular among European colonists who took the view that local stocks should be replaced with types of higher performance and meat most acceptable in European markets be provided. This phase was prevalent from the late 1800'sunti 1915. From about 1920 until after World War II, emphasis shifted to the use of local stocks. European missionaries started crossbreeding of cattle in India in 1875 when the Taylor breed of cattle was developed around Patna, Bihar, by crossing of Shorthorn bulls with native cows. European planters started crossbreeding native cows with Ayrshire, Friesian and Jersey in the Nilgiri district of the Madras state about one and a quarter century back.

Crossbreeding in the Nilgiri area of Madras State and hilly regions of Assam and Bengal with Ayrshire, Holstein and Jersey bulls brought by European missionaries and tea-planters was also initiated around the same time. Military Farms were the next to take up most extensive crossbreeding in 1891 where they began using European breeds like Friesian, Jersey, Guernsey, Ayrshire and Shorthorn. The Zebu breeds used were Sahiwal, Hariana, Tharparkar, Sindhi and Gir.

Crossbreeding at Imperial Dairy Research Institute, Banglore was started in 1910, involving Aryrshire bulls and Haryana cows. The experiment was expanded to Sahiwal in 1913 and Red Sindhi in 1917. In 1938, crossbreeding of Red Sindhi with Holstein Friesian was started.

Livestock Research Station, Hosur (Madras State) initiated crossbreeding of Ayrshire with Red Sindhi in 1919. Indian Agricultural Research Institute, Pusa (Bihar) started crossbreeding with Sahiwal cows in 1920 and Allahabad Agricultural Institute started systematic work for evolving a new milch breed in 1924. The Royal Commission on Agriculture appointed by the Government of India in 1926 pointed out that the owners of dairy cattle should aim at 3500 litres milk yield per annum based on crossbreeding of local cattle with exotic dairy breeds.

The Agriculture Institute, Naini, Allahabad started a crossbreeding programme in 1924 with four exotic breeds namely Holstein Friesian, Brown Swiss, Guernsey and Jersey many bilateral projects started at different locations in the country during the 1960's. They were the Indo Danish Project at Hessarghatta (Karnataka) in 1961, the Indo Swiss Project in Kerala in 1963 and Indo German Project at Mandi (Himachal Pradesh and Almora, Uttarakhand) in 1963. Systematic research programmes for enhancing milk production through cross breeding of European and Indian breeds of cattle was started in India with a project on "Behaviors Patterns of Zebu crossbreeds with exotic Dairy breeds" initiated by the ICAR during 1963 at IVRI, Izatnagar and HAU, Hisar. It involves crossbreeding of Haryana with Holstein Friesian, Brown Swiss and Jersey. The project involved four more stations namely Rahuri (Maharastra), Jabalpur (Madhya Pradesh) lam (Andhra Pradesh) and Dharwar (Karnataka). The original mating plan was to produced four types of crossbreed from each of three exotic breeds F1, ¾ breeds produced through breeding F1 females with the same or other exotic breed, back cross to paternal breed, F2 by inter se mating of F1 and three breed crosses by mating males and females from two different F1 crosses in all six possible combinations.

Board of Agriculture and Animal Husbandry recommended grading up of non-descript cattle with superior indigenous breeds in 1940. The Indian Council of Agricultural Research (ICAR) in 1949 recommended development of non-descript population into dual-purpose breeds. In 1961, Central Council of Gosamvardhana and Animal Husbandry Wing suggested crossing of non-descript cattle with exotic dairy breeds like Holstein-Friesian, Brown Swiss and Jersey for bringing faster increase in milk production. Scientific Panel of Animal Husbandry Department set up by the Union Ministry of Food and Agriculture in 1965 suggested selection among the indigenous superior breeds, grading up of non-descript cattle with established defined breeds and crossbreeding with exotic dairy breeds in an intensive and coordinated manner. The Panel also recommended that bulk of the exotic inheritance should be obtained from Jersey breed and the crossbreeding with Brown Swiss and Holstein may be tried to a limited extent. Fourth Five-Year Plan further laid more stress on crossbreeding of cattle with exotic dairy breed.

Summary of the findings of several workers and reviewer on the subject over the last 50 years

After the initial slow start during the sixties, cross breeding spread all over the country like wild fire and in its wake has also brought in problems of overzealous application and issues related to sustainability. The breeding policy prescribed by the government of India was scientifically and environmentally appropriate, but the application of the policy was universally mismanaged by all most all states except Kerala, parts of Gujarat and Andhra Pradesh. Census enumeration of cross bred separately, started only with the 1982 census round. Successive rounds of livestock census thereafter clearly established the speed with which cross breeding spread in different states across the country. The demand for cross breeding of cattle is high in all states except Rajasthan and Gujarat, where the agro-climatic conditions are extremely adverse for cross bred cattle. The governments of Rajasthan and Gujarat are also reluctant to promote cross breeding of cattle in these states as the indigenous breeds in Rajasthan and Gujarat are some of the best dairy and draught breeds in India and have immense scope for development through selective breeding among them. In states like Kerala and Punjab, cross bred cattle has virtually replaced the indigenous cattle and now account for 70 per cent of the breedable female cattle population in Kerala and 80 per cent in Punjab (livestock census 1997). The other states with large cross bred populations are: Uttar Pradesh, Tamil Nadu, Maharashtra and West Bengal, though breedable female cross bred account for less than 10 per cent of total breedable female in Uttar Pradesh and West Bengal.

Female among cross bred cattle are growing at the rate of almost 10 per cent per annum. The rate of growth would have been much higher had the AI Service in India been of better quality: 85 per cent of the total 24.5 mln AI in 1999 was for generating cross bred (as in the previous years since 1980), but they result in less than 10 per cent (?) pregnancies and even less in terms of calves born. As there is no direct measurement of the results of AI in India, the number of calves born to AI is any body's guess. However the livestock census enumeration of the cross bred cattle is a fair estimation of the success of AI for cross breeding: between 1987-'92 the total number of AI for cross breeding was around 50 mln and the incremental cross bred population between 1987-'92 was only some 3.81 mln: some 7.62 per cent of AI resulting in a cross bred calf. It is true that the incremental cross bred numbers per census round would have been higher and hence the per cent of successful AI, if cross bred male had the same potential for survival. (This would however improve the success rate of AI only marginally).

To answer some of the vital questions, viz. (i) suitability of exotic and indigenous breeds in crosses, (ii) appropriate level of exotic inheritance (1/2 Vs 3/4), (iii) effect of inter-breeding crosses, and (iv) the importance of genotype × environment interaction, a crossbreeding program entitled "Behaviour pattern of Zebu crossbreds" was initiated during the 4th Plan by the ICAR which came into operation from 1.4.1968 at IVRI, Izatnagar and at Hisar centre of PAU, Ludhiana (presently CCS HAU, Hisar). At these units Hariana was to be crossed with Friesian, Brown Swiss and Jersey frozen semen of high merit bulls under a planned mating program. Later this project was renamed as All India Coordinated Research Project (AICRP) on Cattle and started functioning from 1.4.1969. The coordinating unit of the project was established at IVRI, Izatnagar. In 1970, three more units namely APAU, Lam; MPAU, Rahuri and JNKVV, Jabalpur with Ongole as the foundation breed at Lam, and Girat the two remaining centres were added to the project. In 1972 the UNDP/ICAR/PL-480 international crossbreeding project at Haringhata with Hariana breed was also merged in the AICRP on cattle. The National Dairy Research Institute (NDRI) had also taken up similar research projects involving these exotic breeds and Sahiwal, Red Sindhi and Tharparkar as native breeds for synthesis of high yielding crossbred strains.

The results from these and other similar projects indicated that Holstein crosses irrespective of any indigenous breed and the agro-ecologies involved produced the highest quantity of milk followed by Brown Swiss and Jersey crosses given the necessary feed, health and management inputs. There was little to gain by introducing exotic inheritance beyond 50% either from one or two exotic breeds. The decline in milk production through interbreeding of crossbreds did not appear to be large. The results also indicated that in areas with good feed resources specially irrigated cultivated fodder, crossbreeding of indigenous non-descript and low producing cattle with Holstein and stabilization of exotic inheritance at 50% through interbreeding and further improvement through selection may be adopted.

Based on the available results from the crossbreeding experiments, the current breeding policy recommended by the National Commission on Agriculture (NCA) and adopted by Central and State Governments again laid emphasis on selective breeding in the breeding tracts of well-defined breeds of cattle, upgrading of non-descript cattle by crossing with defined superior breeds and crossbreeding with exotic breeds in hilly and urban areas and around industrial townships to ensure adequate milk supply where facilities for rearing and maintenance of high yielding cattle exist. Amble and Jain, Katpatal, Bhat, Arora et al. and Taneja et al. have extensively reviewed crossbreeding work in cattle in India.

Examine of some of the important work published subsequently to these reviews on crossbreeding of dairy cattle

Most of the extensive results reported on cattle crossbreeding in India are based on data from military farms. In these farms a policy of crossbreeding with Bos taurus breeds was adopted already at the beginning of this century. The breeds introduced were Shorthorn and Ayrshire, and later also Friesian. In some periods Bos taurus and Bos indicus bulls were used in alternating generations (criss-crossing). Amble and Jain collected data from nine military farms over a period of 22 years (1934–55). All animals were sired by either zebu or European type bulls. Among the traits studied were age at first calving, first lactation yield, calving interval, and viability. In order to adjust for possible period-to-period variation due to environmental changes, constants were fitted to periods (five years) and grade groups (1/4 to 31/32 exotic inheritance) simultaneously. The analysis was carried out for each farm separately. The results presented were for about 1000 Sahiwal and Red Sindhi crosses with Friesian (1) and Ayrshire. It was concluded that with respect to production characters half-bred and five-eighths excelled all other grades, irrespective of breed used in the crosses. The same grades were the best in viability.

The work on crossbreeding between Zebu (Bos indicus) and European type (Bos taurus) cattle in India was fist reviewed by Amble, Jain and Acharya. The most of the results reported on cattle crossbreeding in India are based on data collected from Military Dairy Farms. In these farms a policy of crossbreeding with Bos taurus breeds was adopted at beginning of this century. The breeds used for crossbreeding were short horn and Aryshire and later also Jersey and Holstein Friesian.

Amble and Jain indicated that with respect to production characters ½ and 5/8 excelled over all other grades, irrespective of breed used in the crossed. The same grads were also showed best viability.

Katpatal [7] studied records on 521 Sahiwal × Holstein Friesian crossbred cow (1447 lactation) belong to on Military Dairy Farm. The proportions of Holstein Friesian inheritance among these animals were 5/16 to 15/16. Estimated results indicated that intermediate grades were superior in growth rate and milk production. A quadratic regression function fitted to the least squares mean showed and optimum at 5/8 Holstein Friesian in heritance with respect to milk yield. The author used multiple regression technique to separate heterotic effects from additive breed effects and estimated the amount of heterosis for milk yield in F_1 crosses at 35-45%.

The average milk yield per day of calving interval was estimated for 97 Sahiwal and 648 Holstein Friesian × Sahiwal crosses. The results obtained for Sahiwal, 1/4 HF, 1/2 HF, 5/8 HF and 3/4 HF were 4.52, 5.11, 6.40, 6.58 and 5.98 kg respectively. The differences between 1/2 HF, 5/8 HF and 3/4 HF were not significant [8].

Bhat et al. [9] the data were collected 70 Sahiwal and about 1800 Sahiwal × Holstein Friesian from eight Military Dairy Farms over a period of 30 years (1939-68). The traits studied were age at first calving first lactation yield, lactation length, calving interval service period and dry period. The estimated results indicated that age at first calving decreased with increasing proportion of Holstein in heritance up to 50%, there after nuclear was seen. First lactation yield and lactation length increased up to 38/64 Holstein grade. The lowest age at first calving and the highest lactation yield was observed for 63/64 Holstein.

On the basis of the same data, Taneja and Bhat [10] estimated additive and hetrotic effects by regressing the least squares means obtained for the various grades on the production of Holstein in heritance of sire and dam and proportion of heterozygosity.

Effects of proportion of Holstein inheritance in sire and dam were significant for all body weight and first and first lactation yield. Breed of sire had significant influence also on age at first calving and first lactation length, while length of first service period, first calving interval and first dry period were not significantly affected by proportion of Holstein in sire and dam. Significant effects of heterosis were found for weight up to six months age at first calving, length of first calving interval and length of first dry period. For first lactation milk yield a non-significant positive effect of heterosis was observed, corresponding to about 5% heterosis in F_1. A significant difference between regression on breed of sire and breed of dam was found for only one out of twelve traits examined.

Rao and Nagarcenker [11] collected the data from 9 dairy farms to study first lactation yield (total and 300 days), lactation length and calving interval least squares analysis was used to study the effect of genetic and nongenetic factors.

Rao and Nagarcenkar [11] revealed that milk yield in all grads with less than 50% Friesian inheritance were significantly interior to all grades above this level. The highest yield was observed for pure bred Friesian, followed by 50% Friesian (preassembly F_1). A significant effect of grades was found also for lactation length but not for calving interval.

Rao and Taneja studies data on more than 3500 Holstein – Friesian × Zebu (Mostly Sahiwal) crossbred cows on ten military farms. The records were collected from 1967 to 1975. The traits were studied were age at first calving, first lactation (305 days) milk yield, first lactation length and first calving interval. Least squares techniques were used to study the effect of genetic and non-genetic factors. The results of this study revealed that 1/2 Holstein Friesian was significantly superior to all other groups in first lactation milk yield in both the regions and for age at first calving and calving interval in the north region, while no such interaction was found for first lactation milk yield. Differences among the four genetic groups were small except for calving interval, which was longer in two groups with 75% exotic in heritance than in the two F_1 groups. There was no significant difference between the Holstein-Frisian and the Red Dane F_1 crosses.

Matharu and Gill [12] used the data of Military Dairy Farm to compare life time production and reproduction efficiency of the various genetic groups. Cows with 5/8 Holstein – Friesian inheritance had the highest lifetime production and also the highest milk yield per day of protective life, while milk yield per day of total life was highest in the half-bred. Deshpande and Bende [13-15] examined first lactation milk records of 1346 Friesian × Sahiwal crosses maintained at four military dairy Farms of southern region and highest milk yield was observed in 1/2 F and 5/8 F, when the proportion of Friesian in heritance increased above this level there was a slight decrease in yield. Length of calving interval did not differ significantly among the crosses, but grades with intermediate levels of Friesian inheritance had the shortest calving interval.

The crossbreeding of zebu breeds with Red Dane, Hoistein-Friesion and Jersey bulls was started in 1968 at Livestock Research Centre/ Instructional Dairy Farm of G. B. Pant. University of Agriculture and Technology, Pantnagar. With the objective to evolve high yielding crossbreds. The half-bred (F_1) were inter-see mated to produce F2 generation and also crossed to pure Holstein-Friesian or Red Dane or Jersey bull to produce animals having 75% exotic inheritance.

Later on, selective breeding was started among animals of different grades with different exotic inheritance and they were crossed in such a way that the level of exotic inheritance is maintained around 62.5 per cent of exotic inheritance.

Differences among the four genetic groups were small except for calving interval, which was longer in the two groups with 75% exotic inheritance than in the two F_1 groups. There was no significant difference between the Holstein-Friesian and the Red Dane F_1 crosses. Data on Sahiwal cows and Holstein-Friesian × Sahiwal crosses at five military farms in Northern India over more than 30 years (1942–1976) were used by Matharu et al. [12] to compare lifetime production and reproduction efficiency of the various genetic groups. Cows with 5/8 Holstein-Friesian inheritance had the highest lifetime production and also the highest milk yield per day of productive life, while milk yield per day of total life was highest in the half-bred.

Military farms were the source of data also in a study by Ganpule and Desai [16], who compared the efficiency of milk production in various Sahiwal × Holstein-Friesian crosses. Milk production efficiency, defined as milk yield per day of life up to end of 5th lactation, increased almost linearly with increasing proportion of Holstein-Friesian inheritance. The Red Dane bulls used at Bangalore Farm originated from an importation of Danish cattle to the Indo-Danish Project in the Bangalore area. Results obtained at this project were reported by Madsen [17]. At the project farm purebred Red Dane cows born in India were found to produce less milk than the cows imported from Denmark. A milk recording scheme provided data on the performance of various genetic groups in the villages. Most improved local cattle were crossbreds between European and local cattle, but few were first crosses. As a group they were assumed to carry approximately 50% Bos taurus genes. Although they had a fairly satisfactory milk yield, they were out produced by the Red Dane crossbreds. The highest milk production and the shortest calving interval were observed for the Red Dane crosses with Red Sindhi.

Brown Swiss was the source of exotic inheritance in the Indo-Swiss projects in Kerala and Punjab. The project in Kerala started in 1963 with 30 bulls and 45 cows imported from Switzerland. The local stock was nondescript cattle from the area, showing traces of improved Indian dairy breeds (Red Sindhi) as well as of European breeds. Cows with 50 to 75% Brown Swiss inheritance produced about three times as much milk as the local cows, and also slightly more than purebred Brown Swiss. All crossbred groups were younger than both parental breeds at first calving, and had shorter calving intervals.

The Indo-Swiss Project in Patiala, Punjab, was initiated in 1971. Fifteen Brown Swiss bulls and 86 females were imported from Switzerland in two batches, and used for crossbreeding with Sahiwal; ten American Brown Swiss females were also incorporated in the herd. Brown Swiss × Sahiwal crosses (F_1) produced twice as much milk as purebred Sahiwal, and also more than purebred Brown Swiss. A comparison between imported and locally-born Brown Swiss cows showed that the imported cows were superior in milk yield, while those born in India were younger at first calving and had shorter calving intervals.

A large scale crossbreeding experiment with cattle was initiated at the National Dairy Research Institute, Karnal, in 1963. Sahiwal, and a few Red Sindhi, females were mated to Brown Swiss bulls (imported semen) to produce an F_1 generation. At later stages backcrossing to Brown Swiss and inter see mating of F_1 took place. Data collected up to 1976 were examined by Taneja et al. [18,19]. Differences between groups were significant only for age at first calving. Numbers of animals included in the study were not reported. In the later paper [19] results from the investigation on Sahiwal crosses were presented. Among the traits studied were age at first calving, first lactation milk yield (actual and 305 days), first lactation length, and calving interval.

The authors used the estimated least squares means as dependent variables in a multiple regression analysis in which proportion of Brown Swiss inheritance in sire and dam, and proportion of heterozygosity were the independent variables. The analysis showed widely different regression coefficients for breed of sire and breed of dam, suggesting different maternal effects of the two breeds (standard errors of estimates were not reported). Heterosis, estimated as twice the difference between F_1 and F_2 amounted to 1160 kg for milk yield. This was 37% of the F2 mean (or 58% of estimated midparent mean). When estimated from the multiple regression analysis heterosis for milk yield was 735 kg (35% of midparent mean). Substantial amounts of heterosis were observed also for age at first calving and calving interval.

Rao and Nagarcenkar [11] used data from the same project, but slightly larger numbers of records. The ranking of different genetic groups was as in Taneja et al. [19], but F2 came out slightly worse and 3/4 BS slightly better. The set-back from F_1 to F_2 was nearly 700 kg of milk. For lactation length and calving interval changes from F_1 to F_2 were non-significant, but in the undesirable direction also for these traits.

Bhatnagar et al. summarized records of Brown Swiss crosses at NDRI, Karnal, up to the end of 1980. The review confirmed the large decline in milk yield from F_1 to F_2 found in the studies mentioned above. From F2 to F3 no further decrease was observed. The backcrosses to Brown Swiss bulls (3/4 BS) were in general intermediate between F1 and F_2 and would even after discounting for expected loss of heterosis from the first to subsequent generations (inter se mating of 3/4 BS) be predicted to out yield F2.

Sharma et al. reported yields and percentages of fat and solids-not-fat (SNF) for various genetic groups in the same experiment. Differences in fat and SNF percentages were small and non-significant. The ranking of various crosses with respect to fat and SNF yields was therefore similar to that for milk yield. F2 produced 27% less fat and SNF than F1. In another project at NDRI, Karnal, bulls of three European type breeds (Friesian, Brown Swiss, Jersey) were crossed with Tharparkar cows. Females of the three F1, crosses were mated with Friesian bulls to produce offspring with 75% European inheritance.

Among F1 crosses Friesian had the highest and Jersey had the lowest milk yield, and their daughters sired by Friesian bulls ranked similarly. Milk yield decreased and calving interval increased when the proportion of exotic inheritance increased from 50 to 75%. There was also a marked increase in calf mortality [20].

Jadhav et al. [21] compared dairy merits of different crossbred groups in the NDRI herd. The groups compared were Holstein × Tharparkar (HT), Holstein × Sahiwal (HS), Brown Swiss × Tharparkar (BT), Brown Swiss × Sahiwal (BS), and Jersey x Tharparar (JT). Whether the cows were F1, F2, or a combination of the two, was not reported, only that they were halfbreds. Number of cows per group ranged from 12 to 39. The data comprised records for the first four lactations. Dairy merit was defined as energy in milk produced in per cent of energy consumed, the latter being predicted from fat-corrected milk yield, body weight, and change in body weight during lactation. The overall least squares means obtained were 28.8 ± 0.3, 28.8 ± 0.5, 26.0 ± 0.4, 26.6 ± 0.1, and 26.2 ± 0.3, for HT, HS, BT, BS, and JT, respectively. It was concluded that Holstein crosses (HT and HS combined) were significantly superior to Brown Swiss crosses (BT and BS combined) and JT crosses in dairy merit.

At Haringhata Livestock Farm (near Calcutta) crossbreeding work began in 1957–58, when Hariana and nondescript local (Indegenous) females were mated to three Jersey bulls, two from U.S. and one from Australia. Later this project was extended to the adjacent Kalyani Farm and continued with Jersey and Friesian semen obtained from Australia. Data collected up to 1974 on Hariana and Jersey × Hariana crossbreds were analysed by Parmar et al. [22]. The study included records on 671 F1 and 261 F2 cows (sired by 17 Jersey and 58 F1bulls, respectively) in addition to 149 purebred Hariana. The traits studied were age at first calving, lactation (305 days) milk yield, calving interval, milk yield per day of calving interval, and dry period. Both crossbred groups were considerably younger than Hariana at first calving, and had higher milk yields, shorter calving intervals, and shorter dry periods. Age at first calving was slightly higher (1.9 months) for F2 than for F1, milk yields were lower (about 20%), and calving intervals slightly longer. Heterosis, estimated as twice the difference between F1 and F2, and expressed in% of F1 means, was -12, -5, and 42 per cent, for age at first calving, calving interval, and lactation (305 days) milk yield, respectively.

In 1968 a large scale cattle crossbreeding experiment was initiated at Haringhata. The experiment formed part of the project Improvement of Milk Production in the Calcutta Area, which was sponsored by UNDP. Foundation cows of the Hariana breed were mated by artificial insemination to Friesian, Brown Swiss, and Jersey bulls from U.S. and (in the case of Friesian and Jersey) U.K. of the resulting F1 females half were bred to an F1 bull from the same cross, and the other half to a bull of the paternal breed. The production of F1 continued in order to have contemporary groups of F1, F2, and backcrosses (3/4 exotic inheritance) of each of the three exotic breeds. Records collected at Haringhata from 1959 to 1977 were evaluated by Bala and Nagarcenkar. The Friesian crossbreds excelled in milk yield, but were slightly older at first calving and had slightly longer calving intervals than Jersey crosses. A serious decline in performance from F1 to F2was observed in both crosses: F2 were about eight months older at first calving and produced about 30% less milk. They had also much longer calving intervals. Purebred Friesians and Jerseys were better than any of the crosses, but the pure exotics were kept in separate units, and preferential treatment cannot be excluded. In milk yield F1 values were 15 to 20% above midparent means.

In 1968 a project entitled Behaviour Pattern of Zebu Crossbreds was initiated at the Indian Veterinary Research Institute (IVRI), Izatnagar, and Hariana Agricultural University (HAU), Hissar. The project involved crossbreeding of the Hariana breed with Holstein, Brown Swiss and Jersey. Subsequently the project was renamed the “All India Coordinated Research Project on Cattle” (AICRPC). In 1970 the project was extended to three more institutions: Andra Pradesh Agricultural University (APAU), Lam; Mahatma Phule Krishi Vidyapeeth (MPKVP), Rahuri; Jawaharlal Nehru Krishi Viswa Vidyalaya (JNKVV), Jabalpur.

The zebu stock was Ongole at the first centre and Gir at the two others. In 1973 the crossbreeding experiment at Haringhata (CBP) was merged with the AICRPC, thus bringing the number of centres to six.

Find out new breeds or types for cross bred foundations

The details of the crossbred strains developed/being developed so far along with their current status including production and reproduction potential have been reviewed.

The breeding policy of this breed dates back to 1924 at Allahabad Agricultural Institute. Hariana, Sahiwal, Gir and Kankrej cows were crossed to Holstein-Friesian, Brown Swiss, Guernsey and Jersey bulls. The crossbreeding in 1934 was, however, restricted to Jersey and Red Sindhi and the crossbreds were backcrossed to Red Sindhi. This policy was followed in the expectation that genes for high milk production would be introduced into the crossbreds by initial crossing and deterioration of the heat and disease-resisting qualities of Indian cattle would be prevented by backcrossing to Red Sindhi. This backcrossing was continued for 18 years till 1952.

The crossbreeding policy was modified in 1953 and the Jersey bulls were used on Red Sindhi cows and on cows with 7/8 or more Red

Sindhi inheritance to evolve a crossbred, to be called 'Jersind' having between 3/8 to 5/8 Jersey inheritances. In 1955, since Brown Swiss was found to be most heat tolerant, it was used instead of Jersey for crossbreeding on pure Red Sindhi cows and on cows with 7/8 or more Red Sindhi inheritance to evolve a crossbred, to be called 'Brownsind' having between 3/8 to 5/8 Brown Swiss inheritance.

Crossbred cows of either Jersey or Brown Swiss inheritance produced more milk and had superior breeding efficiency than Red Sindhi cows. Survival rate and mortality of crossbreds and of Zebu were more or less identical. First lactation 305 days milk production was about 53% more in Brown Swiss × Red Sindhi half bred (6076 lb) as compared to Red Sindhi cows. Age at 1st calving greatly decreased by the introduction of Jersey genes. The half bred Jersey-Red Sindhi cows calved earlier (29 months) and also produced more milk in the first 305 days of their first lactation (1968 kg) than the Red Sindhi cows. They also exceeded Red Sindhi cows in the total life production by 2.09 times. The average lactation yield of Jersind cows declined to 1437 kg in later generations. The breed has shown deterioration over the years mainly because of small numbers and is only confined to the farm.

The project for the development of 'Jerthar' breed of cattle was initiated in 1958 at the NDRI, Bangalore. Jersey bulls of Australian and American strains were mated to Tharparkar cows. Four bulls of each strain were used. Inter-breeding was adopted among first generation progeny and half bred males of Australian strain Jersey were mated to halfbred females of American strain Jersey and vice-versa to maintain only 50% exotic germplasm among the crossbreds. F_1 bulls were selected from the high-yielding Tharparkar dams. Bulls were further selected on the basis of performance of their daughters. Semen of bulls was also frozen for use after the evaluation of daughters' performance. The same policy was repeated for the F_2 and F_3 generations. The performance data revealed that the first generation Jerthar daughters were superior to their Tharparkar dams in all economic characters. But this breed could not sustain for long periods because of limited breed size and lack of systematic selection program.

In 1980, when all the Brown Swiss crossbreds were merged to form 'Karan Swiss', the herd included 86 per cent half breds, 6.4 per cent cows above 50% exotic inheritance, 4.8 per cent cows below 50%exotic inheritance and 2.8 per cent cows with unknown inheritance. Presently, most of the Karan Swiss cows have 50% level of exotic inheritance.

The comparative performance with respect to age at first calving and lactation milk production of various Brown Swiss crossbreds from 1966 to 1980 indicated that F_1 crossbreds were the best followed by 3/4 and the F_2 were the poorest. The F_1 crossbreds had the lowest age at first calving of 30.8months, highest first lactation production (305 days/less) of 2933 kg and first calving interval of 421days. The average performance over all the lactations was 3351 kg for 305 days/less milk yield, 322days for lactation length and 407 days for calving interval. The next best crossbred group was 3/4Brown Swiss × 1/4 Sahiwal with average age at first calving of 31.3 months, first lactation (305 days/less) milk production of 2687 kg and first calving interval of 408 days. The all lactation (305 days/less) production was 3055 kg with average lactation length of 334 days and calving interval of 411days. The other genetic groups had performance lower than F_1 and 3/4 but all crossbred groups were better than the indigenous breed groups.

There was no significant evidence of non-additive genetic effects (heterosis) with respect to growth, milk production, age at maturity and reproduction efficiency. Therefore, in April 1980, the breeding committee of the Institute decided to merge all genetic groups and to practice selective breeding for further genetic improvement of the crossbreds. The level of exotic inheritance was desired at 1/2 to 5/8. The cows were selected on the basis of their expected breeding value (EBV) and the young males reserved for breeding were selected on the basis of their pedigree performance. The age at first calving in Karan Swiss cows averaged 926 days, which is shorter to Sahiwal cows. The average 1st lactation 305 days milk yield was 3195 kg in 330 days.

The milk production has shown phenotypic trend of 14 kg per year from 1982 to 1992. The 1st calving interval averaged 415 days.

Singh et al. [23] reported that the phenotypic trend in Karan Swiss for body weight at different ages was significant and positive and for age at 1st calving it was significant, negative and in desirable direction. The annual phenotypic change in 1st lactation yield was positive but small in magnitude (0.31% of herd average) in Karan Swiss animals [23].

The breeding committee of the Institute in 1980, thus, decided to merge all crossbreds with 50%or above Holstein Friesian inheritance and to bring further improvement by selective breeding. The new strain was named as 'Karan Fries'. The Karan Fries at the time of merging different genetic groups had approximately half the herd of Friesian crossbred cows having exotic inheritance level of 50%, about a quarter herd having exotic inheritance of 75% Holstein-Friesian and the rest having 75% exotic germplasm from two exotic breeds. The level of exotic inheritance was subsequently reduced to 62.5% by using half bred bulls of high breeding value from other organizations. The main objective of this project was to determine the appropriate choice of exotic breed and optimum level of exotic germplasm for evolving a breed suitable to Indian climatic conditions. The half breds were further mated to Holstein-Friesian to obtain crossbreds with 75% exotic inheritance. Three-breed crosses did not show significant improvement over two-breed crosses. The comparative performance of crossbreds also did not show any significant advantage of having 75% exotic level.

The age at first calving in Karan Fries cows averaged 896 days, which is shorter to Tharparkar cows. The average 1st lactation milk yield was 3619 kg in 316 days. The 1st calving interval averaged 398 days.

Singh et al. [23] reported that the phenotypic trend in Karan Fries for body weight at different ages was significant and positive and for age at 1st calving it was significant, negative and in desirable direction. The average fat% ranged between 4.10 and 4.17 and SNF ranged between 8.58 and 8.75%. Further genetic improvement in Karan Fries animals is being obtained through bull selection program. VIII set of 10 bulls was inducted in June 2003. The bulls inducted in the program had dam's best 305 days yield from 4546 to 6662 kg. Cows with average lactation milk yield of 4500 kg and more are being selected as elite for production of male calves. The V set of 7 bulls has recently been evaluated for 1st lactation 305 days milk yield. Their breeding value ranged from 2350 to 3135 kg [24]. The two ranked bulls with 14.07 and3.43% genetic superiority have been selected for use in nominated mating.

The KLDB imported two consignments of exotic bull semen (Jersey, American Brown Swiss and Holstein) for the production of F_1 bulls. The major component of Zebu in the Sunandini breed is the local non-descript cattle of Kerala, even though one or two attempts have been made to Sahiwal, Gir and Kankrej into the population. Cows of these breeds were employed for the production of F_1 bulls. Originally conceived as a multipurpose breed for milk, draft and meat, this breed is now becoming solely a milch breed [25]. The breed characteristics fixed for the cows are 350-400 kg mature body weight, 28-32 months age at 1st calving, 2300-2700 kg 1st lactation milk yield, 3200 kg overall lactation yield and 4% milk fat. The present breeding policy for Sunandini aimed at creating a new synthetic breed of a crossbred population with exotic inheritance of around 50% from Jersey, Brown Swiss and Holstein. Young bulls are being produced by mating superior Sunandini cows maintained in nucleus farms with proven bulls; mating superior Sunandini cows maintained by farmers in the milk recorded area with proven Sunandini bulls; and mating nondescript Zebu cows with superior Jersey/Holstein or American BrownSwiss bulls.

The average birth and adult weight in Sunandini females was 28.3 and 375 kg. The males were heavier than females by 2 kg at birth and 53% at 4 years of age. Age at 1st calving, service period and calving interval was 32.2 months, 148.2 days and 424.5 days, respectively. Overall lactation milk yield was 2435 kg in 280 days with 3.89% fat. The milk production improved from 1st (1914 kg) to 4th (3024 kg) lactation continuously and declined thereafter. Age at 1st calving and calving interval of this breed were significantly shorter and total milk production was significantly higher than their Zebu parental stock (age at first calving 42.13 months, milk production 400-800 kg). Sundandini animals have been interbred for more than 10 generations. The F_1 animals however are also being regularly produced through mating of nondescript Zebu cows with superior Jersey/Holstein or American Brown Swiss bulls.

Frieswal project envisages to evolve a National milch breed "Frieswal", a Holstein- Sahiwal cross, yielding 4000 kg of milk with 4% butter fat in a mature lactation of 300 days. Military Farms at the inception of the Project had Friesian × Sahiwal crossbreds with very low to a very high Friesian inheritance. The crossbred females with 5/8 HF inheritance named Frieswal were bred with the semen of their own genetic group. Crossbred females having more than 50% exotic inheritance named higher crosses were bred with Frieswal bulls' frozen semen. Lower crosses (less than 50% HF inheritance) were bred with imported frozen semen of proven HF bulls with sire index of above 9000 kg. The mating of higher and lower crosses as described above produced the Frieswal progeny in subsequent generations. Sons of 3/8 elite cows bred with the imported proven HF semen and 5/8 elite cows bred with ranked Frieswal semen were screened to put them under test mating.

Age and weight at first calving averaged 1005 days and 364 kg, respectively. Average service period, dry period and calving interval were 161, 112 and 426 days, respectively. All these reproduction characteristics have shown a declining trend over the period (1997 to 2001) indicating the improvement in desirable direction. Average milk production in 300 days (MY300) and in entire lactation was 3069and 3375 kg, respectively. MY300 averaged 2836 kg in 1st lactation. It improved from 1st to 4th lactation and declined thereafter. About 1.40% cows produced more than 4500 kg and 5.60% cows produced more than 4000 milk in first lactation. Peak yield and lactation length averaged 14.27 kg and 315 days, respectively. A total of sixty-one bulls have been evaluated for their genetic merit based on 1st lactation 300 days milk yield of their daughters. Top ten bulls had their breeding values between 2835 and 2965 kg. Their superiority over the herd average (2703 kg) ranged from 132 to261 kg i.e. 4.89 to 9.68%.

Find out a suitable inheritance for higher milk production in Indian conditions

The original mating plan was to produce four types of crossbreds for each of the three exotic breeds:

- First crossbred generation, F_1.
- Backcross to the paternal breed.
- F_2, by mating males and females from the same F_1 cross inter se.
- Three-breed crosses, by mating males and females from two different F_1 crosses in all (six) possible combinations.

This plan of mating was, however, changed several times. At an early stage it was decided to delete the genetic groups II, III and IV. Instead, F_1 females should be mated to a bull of one of the two other exotic breeds, to produce three-breed crosses with 75% exotic inheritance (two exotic breeds). Later, the two crosses combining Brown Swiss and Jersey were omitted. The number of second generation crosses was thus reduced to four. Finally, males and females of each of these three-breed crosses were to be mated inter se.

At two of the centres, Rahuri and Jabalpur, both with Gir as foundation stock, the mating plan was modified further, as no Brown Swiss F_1 crosses were produced. Consequently only three genetic groups will be present in the second crossbred generation. In 1980, also inter se mating of F_1 males and females from the same cross to produce F_2 groups was taken up again.

The results in F_1 were very consistent across units. Brown Swiss crosses were the oldest at first calving in all the four units where they were represented, while Jersey crosses were the youngest at four out of the six units. At all units Friesian crosses had the highest and Jersey crosses the lowest milk yield, Brown Swiss crosses being almost midway between the two others. Calving intervals were always shorter for Jersey crosses than for the others, differences between Friesian and Brown Swiss crosses being small and inconsistent. In three-breed crosses differences among genetic groups were as expected smaller than in F_1. In general, crosses sired by Friesian bulls had the highest milk yield, while crosses by Jersey bulls were the youngest at first calving and had the shortest calving intervals. Comparisons between F_1 and three-breed crosses are less reliable as the two groups necessarily were non-contemporaries. However, the three-breed crosses were on average slightly older at first calving and had also slightly longer calving intervals, whereas milk yields were rather similar. The Friesian F_1 crosses produced more milk than any of the three-breed crosses at all units except one.

A least squares analysis, taking account of year and season effects, but based on smaller numbers of records, led to similar results. Kaikini et al. [26-28] studied reproductive traits of 96 Friesian × Gir and 84 Jersey × Gir crosses in the Rahuri unit in more detail. Incidences of repeat breeding and reproductive disorders did not differ much in the two crosses (22.0 vs. 19.9% and 36.5 vs. 32.1%, respectively). Differences were slight also for age at maturity (413 vs. 402 days), and age at first service (454 vs. 444 days). However, at first calving Friesian crosses were about 1 month older than Jersey crosses (812 and 766 days, respectively). As to viability, Parekh et al. [29] found no significant difference in mortality rates between Friesian × Gir and Jersey × Gir crosses in the Jabalpur unit.

Panda et al. [30] collected milk records of F_1 crosses of Hariana and Deshi (local) cows with Holstein and Jersey bulls. The cows were kept under rural conditions, and fed paddy straw ad lib. With a supplement of a concentrate mixture according to recommendations (no details given). Daughters of Hariana dams produced more milk than daughters of nondescript (Indigenous) dams, and Holstein crosses more than Jersey crosses. Both differences were highly significant. Chaudhary et al. [31] studied lifetime performance of 101 Rathi cows and Red Danish × Rathi crosses in Rajasthan. The crosses were about 15 months younger at first calving and produced 70% more milk in their first lactation (2319 vs. 1418 kg), but their superiority decreased with increasing age. Duc [32] examined records on production and reproduction traits in Hariana, Holstein-Friesian and Jersey cows along with Holstein-Friesian × Hariana and Jersey × Hariana crosses at the Goverment Livestock Farm Hissar, Hariana. The exotic stock originated from Australia. All groups were treated similarly, with the exception that calves were used to stimulate milk let-down in Hariana and crosses, but not in pure exotics. Traits studied were age at first calving, first lactation milk yield (305 days) and first calving interval. Holstein-Friesian and Jersey were about 18 months younger than Hariana at first calving, and produced twice as much milk, and had shorter calving intervals. Crossbreds were closer to the exotic breed in age at first calving, but almost midway between the parental breeds in the other traits. Holstein-Friesian were older than Jersey at first calving, produced more milk and had longer calving intervals, and the F_1 crosses of the two breeds ranked similarly.

Singh [33] evaluates the performance of crossbreds for lifetime parameters, economics of crossbreds, decline in performance of crossbreds over generations and constraints in performance recording and sire evaluation. The lifetime performance in crossbreds was much higher than indigenous breeds. The Friesian crosses had higher lifetime milk yield, longer herd and productive life and completed more number of lactations than other breed crosses. The lifetime milky yield and number of lactations completed in 75% (two- and three- breed) crosses was relatively low. Variability in performance of crossbreds under field conditions could be ascribed to different availability of inputs, agro-ecological conditions, type of farmer and the indigenous and exotic breeds used in crossbreeding. Crossbred cattle have higher milk productivity and reproductive efficiency hence is more profitable than buffaloes and local cattle. Production performance of F_2 crossbred COWS declined (17-42%) on inter se mating among the F_1 animals, and ways were suggested to minimize it. Major constraints in performance recording and progeny testing have been discussed. The monthly test interval method was more suitable and convenient for computation of lactation yield under field conditions. The least squares method can be used for estimating the breeding values of bulls under field conditions. BLUP and contemporary method used for estimating breeding values using organized farm data.

Singh et al. [34] collected data from history sheet of crossbred cattle maintained at Instructional dairy farm, Nagla of G. B. Pant. University of Agriculture and Technology, Pantnagar. The data pertained to 1170 crossbred cattle from 65 sires were distributed over a period of 35 years from 1970 to 2004. The data were analyzed by the least squares techniques to estimate the means, genetic and phenotypic parameters of first lactation and lifetime traits, The overall mean of age at first calving, first lactation milk yield, first lactation period, first dry period, first calving interval, first service period, herd life, productive life, total lactation length, lifetime milk yield and lifetime milk yield/day of productive life were found as 1350.52 ± 13.48 (days), 3093.65 ± 37.17 (days), 361.42 ± 3.61 (days), 177.20 ± 6.47 (days), 538.60 ± 6.66 (days), 271.32 ± 0.75 (days), 1633.22 ± 20.56 (days), 1515.75 ± 20.56 (days), 1305.18 ± 20.37 (days), 9234.45 ± 133.75 (kg) and 6.85 ± 0.14 (kg) respectively.

The effect due to genetic group / breed was non-significant on first lactation and lifetime traits except first calving interval and lifetime milk yield. The least squares means of first lactation milk yield in the study reveals that crossbred animals of HFXRDXJ had higher milk yield and followed by SXHFXJ and SXHF crossbreds than the other genetic groups while four breed (S xHFXRDXJ) crossbred cattle had lowest first lactation milk yield. The least squares means of AFC revealed that crossbred animals of SXJ had lowest age at first calving while highest age at first calving was observed for SXHFXRDXJ crosses (Table 1).

Traits	No of observations (N)	Mean ± S.E.	Standard Deviation	C.V.%
First Lactation Traits				
AFC	1085	1350.50 ± 17.38	290.08	21
FLMY	1085	3098.94 ± 41.30	927.27	28.91
FLP	1085	361.86 ± 4.52	88.16	23.37
FDP	1085	176.95 ± 6.37	142.48	80.21
FCI	1085	538.82 ± 5.85	166.95	30.56
Life Time Traits				
HL	1085	1646.15 ± 21.03	519.44	30.25
TLL	1085	1317.31 ± 18.67	508.58	36.84
LTMY	1085	9316.13 ± 30.75	3297.2	34

Table 1: First Lactation and Lifetime Traits [35].

Variations in economic performance between crosses of different breeds have also been observed. Hemalatha et al. [35] compiled reports in which Friesian crosses, Jersey crosses and local cattle kept indifferent parts of tropics were compared. These reports showed that the cross-breds produced higher profits per kilogram of milk produced than the indigenous Zebu animals. It was also observed, however, that maintenance costs were highest for Friesian crosses, followed by Jersey crosses and lowest for local cattle. The economic impact of cross-bred cows in smallholder farming systems has been demonstrated in a number of studies. Some of these studies [36-38] reported that in areas where cross-bred animals can be maintained, farmers incorporating them into their production systems had higher household incomes than those with pure indigenous breeds.

In spite of the great potential of cross-breeding as a livestock improvement method, it has not led to a wide-spread increase in milk production in the tropics [39]. Owing to several challenges, cross-breeding has yet to be successfully and sustainably adopted and practiced in the region [40]. These include (1) limitations of cross-breeding methods; (2) mis matches between genotypes and production system, (3) intermittent funding of programmes and lack of appropriate policies and (4) lack of or limited involvement of farmers in the design of the interventions. Limitations of cross-breeding methods. The many impressive results of grading up on record were mostly achieved at research stations and commercial farms, where the level of management and nutrition of stock is good [41]. The smallholder sector in the tropics, which constitutes the majority of farmers, is at times unable to raise the levels of management and nutrition in line with the requirements of the new genotypes. This often leads to low productivity and high mortality among the animals. Although results from rotational cross-breeding have shown a marked improvement in animal productivity, this improvement method can only be used on large-scale operations, where management is good. The programmes associated with it are not practical for small-scale farmers, whose herd sizes may not justify keeping more than one bull. In the two-breed rotation system, there is great variability in genotypic composition from generation to generation, depending on the sire breed used. This is not practical for small-scale operations, has never been expanded beyond the single ranch programme or replicated elsewhere.

Thus, this programme has had only limited impact as a source of improved genetics to the wider dairy farming community in the hot and humid coastal region of India. The development of synthetic populations has its draw backs, too. First, it takes many years to develop a synthetic population, during which the production environment could change. Second, the development can be expensive.

In addition, pricing policies for milk in country is often poor. Prices paid to the farmers for milk of Cross-bred dairy cattle in the tropics low and cannot support the purchase of feeds or investment in the necessary infrastructure, all of which are necessary to make the production system economically viable [42]. The failure to recognize the different needs of different production systems has also affected the success rate of cross-breeding programmes.

In many tropical countries, past, and, in some cases, ongoing cross-breeding programmes have often been based on a one-genotype-combination-fits-all premise, with HFs being the preferred improver breed even in the hot and humid tropics and under production systems such as stall feeding (zero grazing), where other breeds might be better suited. Such genotype × production system mismatches that ignore the important genotype-by-environment interaction effects are partly responsible for the largely disappointing and poor performance of cross-bred cattle in the tropics and their often insignificant impact [42]. The assumption that production systems can easily be changed and adapted to fit the needs of cross-bred animals seems in many circumstances wrong. In these cases the genetic improvement of local breeds should be considered a more realistic approach. The choice of B. taurus breeds and the level of crossing for different production systems should not only be based on the genetic potential for milk yield, but also on farmers' ability to follow adequate husbandry practices as well as on the available healthcare services and markets. In addition, the availability of adequate, good-quality feeds and water needs to be taken into account, too. Increasing the genetic potential of the animals alone is not enough, the above factors must be considered as well for the full beneficial heterotic effects to be realized. Intermittent funding of programmes and lack of appropriate policies. A well-planned cross-breeding programme requires adequate funding [40]. However, funds in the required amount are not always available, which has caused the interruption of many programs.

Other crossbreeding programs in different states

A broad policy for cattle breeding exists through crossbreeding with exotic dairy breeds in the country. The non-descript and low producing cattle are to be improved in milk sheds of large consuming markets where inputs with respect to feed and health covers are available. Holstein, Brown Swiss and Jersey are to provide bulk of exotic inheritance and the crossbreds to be stabilized around 50%. Jersey is being used for the genetic improvement of local cattle in Assam, Arunachal Pradesh, Bihar, Goa, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Manipur, Orissa, Rajasthan, Tamil Nadu, Tripura and West Bengal. Holstein Friesian in Delhi and Punjab and Holstein-Friesian and Jersey both in Gujarat, Haryana and Uttar Pradesh are being used in crossbreeding program currently. Crossbreeding programs in Kerala, Karnataka, Maharashtra, Punjab and Hariana have been taken up extensively. Efforts for improving dairy cattle in Kerala were made on an intensive scale with the introduction of Key Village Scheme in 1952 and subsequently with the taking up of Intensive Cattle Development Programs. The major impetus to crossbreeding, however, was given through the Indo-Swiss Project in 1963. Kerala does not have any descript breed of cattle. A large population of Brown Swiss and Jersey crossbreds is available now for further improvement through selection. Attempts for recording the performance of farmers' cows are also being made. The State Animal Husbandry Department, Maharashtra carried out the cattle development programs through Key Village Centres, Intensive Cattle Development Programs, Operation Flood Schemes, Cooperative Federations and Bhartiya Agro Industries Foundation, Uruli-Kanchan (since 1978). The major program was to cross the indigenous descript/non-descript cows with Friesian and Jersey to create half bred and subsequently interbred them. The performance of Holstein and Jersey crossbreds under village conditions of Maharashtra reflected 30.4 and 30.3 months age at 1st calving and 2286 and 1696 kg 1st lactation305 days' milk yield.

Punjab has done better than most of the other States in dairy development. The total milk production of the State is 7.30 million tonnes, which is 8.01% of total milk production of the country [43]. There is no descript breed of cattle in Punjab and most of the local cattle are of Hariana type. The State Government had decided to take up crossbreeding with Jersey in sub mountainous areas and with Holstein in the central districts. Crossbreeding with Brown Swiss was done in Patiala, Sangrur, Bhatinda and Faridkot districts under Indo-Swiss Project. Brown Swiss was however discontinued in 1977 due to lower performance of its crossbreds and Holstein was started in use. The exotic inheritance was kept between 50 and 60%. The overall average daily milk yield was3.29 litres in local cattle and 5.35 litres in crossbred cows. The average lactation milk production per animal was 2017 and 915 litres for crossbred and local cows, respectively. The crossbred animals also yielded between 2500 and 3500 litres per lactation depending upon feeding and management.

The breeding policy of Karnataka State is crossbreeding of non-descript cattle with Jersey, Red Dane and Holstein Friesian and improving other breeds through selection in their respective breeding tracts. The hilly areas are being involved utilizing crossbred bulls. Largest concentration of crossbred animals is around Bangalore varying in exotic inheritance from 50 to 75%. The Indo-Danish project on Cattle Development was started in 1967 with purebred Red Dane at Hessarghatta (Bangalore). Red Dane x Sindhi had age at 1st calving between 846 and 900 days, lactation milk yield 2000 kg and calving interval from 360 to 390 days. Breeding policy of Haryana State includes crossbreeding of non-descript cows with Jersey and Holstein Friesian and grading up with Hariana, Tharparkar and Sahiwal breeds. The farmers of the State are greatly benefitted through the sale of crossbred cows. The average lactation milk production has been noticed 674 litres in local cows and 2210 litres in crossbred cows. Most of the crossbred population available in the country is the result of Intensive Cattle Development Programs. These programs were initiated in 3rd Plan and were strengthened subsequently. The introduction of frozen semen and artificial insemination program in 1970 further improved effectiveness of crossbreeding.

Find out suitable inheritance for grade up the local non-descript animals

The superior performance of crossbreds over the mean of parental breeds has been generally explained due to non-additive gene effects. The results of various crossbreeding studies showed that for age at first calving, the optimum level of temperate inheritance was between 1/2 and 5/8. Beyond this level, the overall adaptability of crossbreds to tropical conditions gradually declined, resulting in increase in age at first calving. For lactation yield, it tended to decline with lower (<50%) and higher (>75%) levels of Holstein inheritance. Crossbreeding resulted in a significant decrease in service period and calving interval, and these were the shortest in crossbreds with 1/2 to 5/8 Holstein inheritance.

Taneja et al. [44] also observed that there was no linear increase in production level above 50% with the increase in the level of inheritance of the exotic parent and it cannot be assumed that gradingup to a total replacement of genes will lead to higher levels of production, at least in cattle. BrownSwiss × Red Sindhi halfbreds produced 53% more milk than Red Sindhi cows.

Agarwala reported two times more milk production in Jersey × Red Sindhi half-bred than the native component. Bhasin et al. [45] observed 188% improvement in milk production inFriesian × Hariana half breds. Heterotic effect of 34% had been reported by Katpatal [7] in Holstein × Sahiwal crossbreds at Military Dairy Farm, Jabalpur that was gradually declined as the fraction of Holstein inheritance deviated from 50%. Taneja and Bhat et al. [33] based on large volume of data reported 4.97% heterosis for 1st lactation milk yield in Sahiwal × Friesian crosses at different Military Dairy Farms. He also observed beneficial heterosis of –4.63% for age at 1st calving, -11.4% for service period, -22.4% for number of dry days and –8.53% for calving interval. Heterosis for birth weight from 1.8 to 7.1% [7] and 8.56% Taneja et al. [32] had been reported in Holstein × Sahiwal crossbreds. Brown Swiss × Sahiwal crosses at NDRI excelled in milk production by 56% in F_1 that was dropped by 24.5% in F_2.

The data generated at Kerala under field conditions reflected 146% rise of milk production in Jersey × local half-bred. Holstein Friesian × Sahiwal half-bred had lower age at 1st calving by 14 months and produced 3.5 times more milk than Sahiwal cows [46]. The increased variation in F_2 over F_1 is expected theoretically when the differences among parental breeds are large. The results obtained from various crossbreeding experiment have revealed that performance of crossbreds was undoubtedly better as compared to native breeds. The use of crossbreeding can be an effective tool for replacing non-descript animals, for this purpose Holstein Friesian and Jersey inheritance with non-descript animals should be maintained around 50-62.5% exotic inheritance level for better production performance.

Consequences of crossbreeding

Dairy owners in Punjab are facing a peculiar problem. Their high-yield, cross-bred cows are so 'alien' to India that they are now stressed by the hot and humid conditions of this country and are displaying an alarmingly high trend of infertility. Scientists of Veterinary College Ludhiana highlight that a majority of clinical cases encountered during animal welfare camps or at field practices are of infertility among cross-bred cows. With an objective to get more milk, dairy owners have gone in for artificial insemination for their animals, using the semen of European bulls. The milk yield of the progeny is high, but their requirements are different. These cows now need cold living conditions and a high-nutrition diet, which the dairy owners are unable to provide. As a result, the cow faces stress and is unable to conceive. That the cows are impregnated with the semen of Holstein-Friesian bulls of Germany and Holland. "This way, the milk yield of the cows goes up considerably.

The owners of dairy farms in the state admit to have gone in for hybridisation at a very high level. Avtar Singh Ratol owns about 200 cross-bred cows, housed at his dairy farm in Saroud village near Malerkotla. He says cows with up to 65 per cent "pure blood" yield 15 to 30 litres of milk daily. "These cows can stand temperatures up to 28 to 30 degrees Celsius. But a number of farmers have gone in for up to 75% hybridization. Those cows give 30 to 50 litre milk daily, but must be kept in the temperatures of 20 to 22 degrees Celsius, with coolers and foggers. Their nutritional requirements are very high too. Most farmers are not able to manage this. As a result, the cows are not able to conceive," he says.

In addition, a lack of supportive national breeding policies and appropriate strategies has contributed greatly to the failure of many programmes. This issue is of major concern to both farmers and technical personnel who are constantly seeking answers on how to maintain the appropriate level of crossing or determine which level of crossing is appropriate for a given production environment. The lack of proper guidelines has led to undesirable consequences, especially at smallholder units where indigenous breeds are upgraded to higher exotic grades without following a defined cross-breeding programme. Participation of farmers in any breeding programme, either for improving local breeds or cross-breeding with exotic breeds, is a crucial point for the success for any livestock improvement intervention. Farmers must have the right to express their opinion and should be involved in decision making processes. This can ensure that new procedures such as data recording can be easily implemented, and that animals that better fit to the management of the individual farmers are bred.

The potential and impact of crossbreeding

Certain advantages exist to assist in addressing the challenges discussed in the previous section. These include:

Availability of a large base population of indigenous cattle; (2) advancements in ART; (3) availability of alternative recording methods; and (4) advances in genomic technology. Well-planned programmes using all or a combination of the existing advantages may lead to a large number of productive cross-bred animals in the tropics.

A considerable number of cattle are found in the tropics. Most of these are indigenous cattle and belong to the Zebu type. The Zebu can be classified into a number of sub groups according to external traits, such as size, origin or utility. It has been proposed that improvement in tropical cattle should be made by selective breeding within the B. indicus race. This has however been shown to be a slow way to meet the fast-growing need for production. The large number of existing animals with unique qualities provides an opportunity to make rapid improvements over a short period, if breeding programmes that cross-breed large numbers of animals with B. taurus milk breeds can be successfully implemented.

Recent developments in ART provide an opportunity for rapid multiplication of cross-bred populations. ART are defined as techniques that manipulate reproductive-related events and/or structures to achieve pregnancy with the final goal of producing healthy offspring in bovine females. Wide spread use of AI has been greatly enhanced by the possibility to freeze semen. In well-structured cross-breeding programmes in the tropics. AI has the potential of increasing the rate at which genetic change happens in the local population by increasing their productive rates of the bulls. Through AI it has been possible to transfer exotic genes to the tropics through imported semen. In some parts of the tropics, the persistent use of AI has yielded impressive results. In India, a well-planned cross-breeding programme resulted in the formation of the Sunandini synthetic breed.

By 1993, Sunandini cattle had contributed greatly to the increase in milk production in Kerala State, India [47]. A successful example for the use of AI for cross-breeding in the tropics is the dairy husbandry programme of the non-governmental organization (NGO) BAIF Development Research Foundation in India. Established in the 1970s in Maharashtra, India, with support from various international development agencies and the government of India, BAIF has built up a successful AI programme. BAIF's programme has served over 4.4million families by establishing over 3500 cattle development centres across most states of India. The centres provide doorstep AI services to farmers accompanied by training and support concerning all aspects of dairy cattle farming [5]. Farmers buy high-quality semen collected at BAIFs own bull station which houses 300 bulls of various exotic and indigenous breeds [5]. The joint efforts of an NGO, the government of India, private sponsors and farmers benefitting from and recognizing the value of this ART have led to a successful, sustainable cross-breeding programme. Following the success of AI, other methods of recovering, storing and implanting embryos, for instance multiple ovulation and embryo transfer (MOET), were developed. This opened up new possibilities for genetic improvement. It has been shown in some studies that well-organized MOET programmes can result in increased selection intensity and reduced generation intervals, which eventually lead to higher genetic gains. It is for example estimated that if nucleus herds are established and heifers subjected to juvenile MOET (before first breeding), genetic gains twice than those obtained through traditional progeny testing programmes can be achieved. Since the middle of the 1990s, another important technique has been developed: ovum pick-up followed by in vitro embryo production (OPU-IVP). In this method, oocytes are harvested from females and fertilized in vitro.

Through OPU-IVP, reproductive rates in females can be increased. For example, if two OPU-IVP sessions are carried out per week, up to 150 embryos and 70 calves per donor can be produced every year. There are two benefits for crossbreeding programmes: The number of females required in the programme is significantly reduced, and it is possible to multiply the number of animals with the required qualities rapidly. If sexed semen is used for in vitro fertilization, the sex of the offspring can be predetermined.

This opens up additional opportunities for repeatedly and rapidly producing cross-breds of specific breed combinations and preferred sex. It has also been proposed that OPU-IVP be used widely as a method for continuous production of F_1 sby using oocysts from spent dairy cows and semen from adapted breeds. In this method, lactation in F_1 cows can be initiated by transfer of F_1 in vitro produced embryos. This strategy eliminates the loss of the heterosis effect and increases the phenotypic variation that results when F_1 cattle are bred to either a pure-bred or cross-bred sire. Wide-scale use of the technologies mentioned above (MOET, OPU-IVP and AI) is, however, not possible in the tropics at the moment because of the high costs involved, the poor infrastructure in many countries and the shortage of technical personnel.

General Observations

Results from over 60 years of research confirm that crossbreeding is the fastest way to improve milk production, but not necessarily to long-lasting genetic improvement of livestock, with the exception of the formation of synthetic breeds. However, results obtained at the various research centres have not been widely transferred to the farming community. This review has provided some reasons for this failure and proposed solutions for overcoming the still widespread problems. Results from a study point to the fact that the milk production performance of the F_1 could be close to being the optimum, but other factor such as reproductive performance also need to be considered to give recommendations on the right combination of exotic inheritance for a particular production system. Maintaining the suitable breed inheritance through grading up and rotational breeding still remains a challenge.

Another way to acquire animals of the required breed combination could be through special contracts with rotational breeders who supply smallholder farmers at an agreed price. The impact of such a move, however, would be limited, as there are only a few large-scale rotational breeders in the tropics. What is more, this approach cannot guard against genetic variation when offspring are mated to animals of different breed composition. It appears, therefore, that maintaining the suitable breed combination from generation to be best achieved through developing synthetic breeds for the different production environments. This approach ensures the creation of a self-replacing population. It also ensures that the farmers deal with one kind of animal, which makes management easier, especially in harsh production environments. The combination of ART with advanced molecular genetics plus the availability of simple recording schemes provide great opportunities for developing and multiplying synthetic breeds at a much faster rate than in previously conducted breeding programmes. Success of this kind of programme requires farmer involvement already at the development stage and long-term. The newly developed methods could, for example, initially be targeted at farmers that have established a community-based breeding programme in which recording and breeding information is shared.

This approach also enables efficient use of technical personnel and equipment as it is available in a single place. More and more exhaustive studies on the various merits of indigenous tropical genotypes still need to be undertaken.

The findings of these studies will help determine which combinations of exotic and indigenous breeds to use, and the level of exotic blood to maintain in the new genotypes. The conservation of indigenous breeds should not only not be ignored but become part of national breeding programmes as this group of animals possesses qualities that make them a valuable resource for present and future generations.

Conclusion

Cross-breeding remains an attractive option for livestock improvement in the country because of the quick results that can be obtained by its use and the potential benefits it has for farmers. Nevertheless, careful assessment should be made on whether or not appropriate intervention strategies need to be put in place for each individual case. The required infrastructure for improved management and market access has to be secured. In most cases, the F_1 crosses perform better than other genotypes, but the continuous production of F_1s and animals of required genetic combinations for the different production environment still remains a big challenge. Production and multiplication of synthetic breeds is perhaps a solution to this problem. The success of any strategy followed to improve results obtained from cross-breeding depends greatly on long-term financial commitment of governments, active involvement of the beneficiary farming communities in the design as well as operationalization of the breeding programmes, and on the successful combination of advances in ART and molecular genetics in breeding programmes. The policy for selectively breeding indigenous breeds of cattle did not takeoff for various reasons.

- Improvement in production and productivity were not spectacular enough to encourage farmers to progressively support it.
- Proven sires among these breeds are not available.
- There were no breeder's organizations for these breeds in their respective home traits to provide technical and advisory services to breeders.

On the basis of findings of these studies following conclusions are drawn

- Exotic inheritance of around 50% is the most ideal for growth, reproduction and milk production, and the yield in higher crosses falls short of theoretical expectations. The grading up, therefore, to a total replacement of genes will not lead to higher production in cattle
- The crosses of temperate with improved indigenous breeds (Sahiwal, Red Sindhi, Gir, Tharparkar) attained the same level of performance under uniform feeding and are superior to crosses from other native cattle.
- Holstein crosses were superior to other temperate breed crosses for growth and production while Jersey crosses have better reproductive efficiency. Decline in milk yield from F1 to F2 generations on account of inter se mating among F1 crossbreds is small. The Target decline in some experiments is due to poor quality of crossbred bulls used.
- The Friesian crossbreds excelled in milk yield, but were slightly older at first calving and had slightly longer calving intervals than Jersey crosses. A serious decline in performance from F1 to F2was observed in both crosses: F2 were about eight months older at first calving and produced about 30% less milk. They had also much longer calving intervals.
- The combination of ART with advanced molecular genetics plus the availability of simple recording schemes provide great opportunities for developing and multiplying synthetic breeds at a much faster rate than in previously conducted breeding programmes.

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