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Breeding a Nation's Milk Bowl: The Genetic Transformation of Indian Livestock through Crossbreeding

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Abstract:

Crossbreeding has been a cornerstone of livestock genetic improvement in India, aiming to combine the high production potential of exotic breeds with the adaptability, disease resistance, and heat tolerance of indigenous animals. Although selective breeding has been practiced since ancient times, organized crossbreeding began during the colonial period with the development of the *Taylor* breed near Patna in 1875, followed by systematic programmes at Military Farms (1891) and the Imperial Dairy Research Institute, Bangalore (1910). After independence, crossbreeding became central to national livestock development through initiatives such as the Key Village Scheme, Intensive Cattle Development Programme, and the Indo-Swiss Project, laying the foundation for modern dairy improvement. The impact of these programmes is reflected in the 20th Livestock Census (2019), which reported approximately 303 million bovines, including 193 million cattle. The exotic and crossbred cattle population increased by 29.3% over the previous census, while the indigenous and non-descript cattle population declined by nearly 6%, underscoring the extensive use of exotic germplasm. Similar breeding efforts have also led to the development of improved sheep (Bharat Merino, Kashmir Merino, Avivastra, Avimaans), goat (Beetal × Alpine and Beetal × Saanen), pig (Large White Yorkshire and Hampshire crosses), and backyard poultry (Vanaraja, Gramapriya, and Kalinga Brown) breeds, contributing substantially to enhanced milk, meat, wool, and egg production. However, the increasing dependence on crossbreeding has raised concerns over the erosion of indigenous genetic diversity and the loss of valuable adaptive traits, including heat tolerance and disease resistance. Consequently, India's breeding policy has shifted toward the conservation and genetic improvement of native breeds through initiatives such as the National Livestock Policy (2013) and the Rashtriya Gokul Mission (2014). This review highlights the historical evolution of crossbreeding in India, species-specific breeding strategies, major synthetic breeds, production gains, and the evolving policy framework supporting sustainable livestock genetic improvement.

Keywords: Indigenous breeds, Exotic germplasm, Heterosis (hybrid vigour), Grading up, Artificial insemination, Livestock genetic resources.

Historical Genesis of Crossbreeding in India:

Crossbreeding, the mating of animals from two different breeds, has long been used to improve livestock productivity by combining the desirable traits of parental breeds while exploiting hybrid vigour (heterosis). In India, organized cattle crossbreeding dates back to 1875 with the development of the *Taylor* breed near Patna through the crossing of Shorthorn bulls with indigenous cows. Around the same time, similar efforts were initiated in the Nilgiri hills of Madras Presidency and the hilly regions of Assam and Bengal using Ayrshire, Holstein, and Jersey bulls. Crossbreeding gained further momentum with the introduction of exotic dairy breeds into Military Farms in 1891 and subsequent breeding programmes at the Imperial Dairy Research Institute, Bangalore, in 1910. These early initiatives were largely localized and aimed at meeting the dairy requirements of the colonial administration rather than implementing a coordinated national breeding programme. The scientific basis of crossbreeding lies in heterosis, or hybrid vigour, a concept first described by George H. Shull (1908) and later applied to livestock breeding by pioneers such as Sewall Wright and Jay L. Lush. By combining the superior production potential of temperate exotic breeds with the heat tolerance, disease resistance, and adaptability of indigenous breeds, crossbreeding has become an effective strategy for improving the productivity and resilience of livestock under tropical production systems.

Cattle Crossbreeding:

Institutional and Policy Evolution:

- The need for organized crossbreeding in India arose from the relatively low productivity of indigenous non-descript cattle, which produced only about 793 kg of milk per lactation under good management and had an average adult body weight of approximately 250 kg. To address this productivity gap, the Indian Council of Agricultural Research (ICAR) initiated a large-scale crossbreeding programme in 1955 for hilly and high-rainfall regions using Jersey bulls. The objective was to determine the optimum level of exotic inheritance that could maximize productivity while maintaining adaptability under village production systems.
- A major milestone was the launch of the Indo-Swiss Project in Kerala (1963), which aimed to develop a high-yielding dairy breed through systematic crossbreeding while promoting dairy-based agriculture among nearly 2,000 farmers in the state's high ranges. The project also introduced frozen semen technology to India, marking a significant advancement in artificial breeding. During the same period, crossbreeding programmes involving Sahiwal and Red Sindhi cattle with Brown Swiss were initiated to develop improved dairy strains.
- The establishment of the Intensive Cattle Development Programme (ICDP) in 1964 marked the beginning of large-scale, organized crossbreeding across the country, and by 1969 crossbreeding had been formally adopted as a national strategy for dairy development. The importation of Brown

Swiss germplasm from Switzerland between 1965 and 1967 subsequently contributed to the development of the Sunandini breed in Kerala. Similar international collaborations further strengthened India's breeding programmes, including the Indo-Danish Project in Karnataka, which utilized Red Dane and Red Sindhi cattle, and the Indo-German Project in Himachal Pradesh, which focused on systematic field performance recording and genetic improvement.

Crossbreeding programmes continued to expand during the 1970s and 1980s. In 1971, ICAR–National Dairy Research Institute (NDRI), Karnal, initiated a systematic crossbreeding programme using Tharparkar cows and Holstein Friesian, Brown Swiss, and Jersey bulls to identify suitable genetic combinations for Indian conditions. The Frieswal Project, launched in 1987, further aimed to develop a high-yielding dairy breed by crossing Holstein Friesian with Sahiwal cattle, targeting an average milk yield of 4,000 kg with 4% fat in a 300-day lactation. Simultaneously, organizations such as the National Dairy Development Board (NDDB) under Operation Flood and BAIF strengthened performance recording, artificial insemination, and field-level genetic improvement programmes. By 1980, the Key Village Scheme had expanded to cover nearly 1.8 million breedable cattle, accelerating the adoption of scientific breeding practices across the country.

Major Crossbred/Synthetic Cattle Breeds Developed in India

Breed	Parent breeds (Indigenous × Exotic)	Year/ Institution	Country of exotic origin	Exotic inheritance (%)
Taylor	Native cattle × Shorthorn	1875, near Patna	United Kingdom	Variable
Karan Swiss	Sahiwal × Brown Swiss	Developed at NDRI, Karnal (1970s–80s)	Switzerland/USA	62.5% (5/8 fixed level, per various studies)
Karan Fries	Tharparkar × Holstein Friesian, a crossbreeding programme initiated in 1971 and the breed developed by 1982 at ICAR-NDRI, Karnal	1982, NDRI Karnal	USA/Netherlands (Holstein)	Fixed at 62.5% HF inheritance
Frieswal	Sahiwal × Holstein Friesian, project started in 1987	1987, Military Farms/ICAR	USA/Netherlands	62.5% (5/8 HF)
Sunandini	Non-descript Kerala cattle × Brown Swiss (with some Jersey and Holstein influence); exotic inheritance maintained at about 50%	1965–67 onward, Kerala	Switzerland/USA	50%

Crossbreeding in India primarily followed a grading-up approach, where indigenous animals were successively mated with exotic breeds to produce F1, F2, and subsequent generations. Once the desired

level of exotic inheritance (typically 50%, 62.5%, or 75%) was achieved, inter se mating among crossbred animals was practiced to stabilize the genetic composition. Selection was based on production performance, reproductive efficiency, and adaptability, with the ultimate goal of developing stable synthetic breeds that combined the productivity of exotic cattle with the resilience of indigenous breeds while retaining the benefits of hybrid vigour (heterosis).

Impact: Production Gains and Concerns of Degradation

The total milk production of the country increased substantially during the initial generations of crossbreeding. Field data from Maharashtra showed 30.4 and 30.3 months age at first calving, with 2,286 kg and 1,696 kg first-lactation 305-day milk yields for Holstein and Jersey crossbreds, respectively, under village conditions.

Analysis of milk production potential in various organized farms revealed that improvement achieved through decades of planned crossbreeding was not commensurate with the money, effort, and resources invested, and that production gains diminished in subsequent generations, largely attributed to lack of selection of F1 bulls, partial expression of heterosis for milk yield, and breakdown of favourable epistatic gene combinations. More broadly, native breeds well-adapted to adverse climate and disease are being lost due to misdirected and indiscriminate crossbreeding with exotic stock, with crossbred populations often showing declining productivity over successive generations, partly attributable to an "elitist" approach that blindly accepted Western notions of what constitutes a superior breed. Indigenous breeds such as Malpura, Chokla, Jaisalmeri, Munjal, Changthangi, and Bonpala have shown notable population decline linked to such indiscriminate crossing.

Buffalo : A Contrasting Case

Unlike cattle, systematic exotic crossbreeding of buffaloes has been minimal, since no exotic buffalo breed superior to Indian riverine buffaloes (notably Murrah, Nili-Ravi, Surti) exists internationally. Instead, the Indian strategy has focused on selective breeding and "grading up" of non-descript buffaloes with superior indigenous breeds, particularly using Murrah bulls to upgrade non-descript buffalo populations across states such as Uttar Pradesh, Odisha, and West Bengal - a strategy supported by NDDB's progeny-testing and semen-station network rather than exotic introgression. India holds the largest buffalo population in the world at about 109.85 million as per the recent census, an increase of roughly 1.1% over the previous census, underlining buffaloes' continued role as major contributors to national milk production, achieved predominantly through within-species genetic improvement rather than crossbreeding with foreign germplasm.

Sheep Crossbreeding:

India has actively pursued sheep crossbreeding programmes since the mid-20th century, aimed at improving both wool quality and meat yield.

- **Wool improvement:**

  Exotic breeds such as Rambouillet and Corriedale have been widely used; Corriedale, originally developed in New Zealand and Australia, is the principal dual-purpose exotic breed imported into India, mainly from Australia, with mature rams weighing 80–100 kg and ewes 55–80 kg, producing 4.5–5.5 kg of greasy wool annually.

- **Meat improvement:**

  Breeds such as Dorset and Suffolk have been used to create synthetic meat breeds like Avimaans, developed at CSWRI Avikanagar by crossing Dorset or Suffolk rams with Malpura or Sonadi ewes.

- **Kashmir Merino:**

  Developed through structured crossbreeding, as was Bharat Merino and Hissardale; the exotic inheritance of Kashmir Merino ranges between 50 and 75%.

Farmers cross the wool-inferior Malpura breed with the higher-wool-yielding Marwari sheep for improved wool productivity, and if unchecked, this indiscriminate crossing may endanger the distinct Malpura breed. Similarly, the unique Garole breed of West Bengal, though not endangered, faces genetic dilution pressure from ongoing indiscriminate crossbreeding aimed at productivity improvement.

Goat Crossbreeding:

- Crossbreeding trials at CSWRI Avikanagar and later under the All India Coordinated Research Project (AICRP) on Goats (relocated to IVRI, Makhdoom, Mathura after 1976) evaluated exotic dairy goat breeds - Alpine and Saanen (both of Swiss/French origin) - crossed with Indian breeds such as Beetal and Malabari.
- Beetal, a good milch breed, produced an average of 156.7 kg milk over a 186-day lactation, while Alpine and Saanen crosses under Indian conditions yielded 308 kg and 286 kg respectively - far below their 1,850 kg and 1,900 kg potential recorded in the USA, though still showing substantial improvement over native breeds.
- Subsequent plans (V Five-Year Plan onward) extended goat improvement work to meat-type crossbreeding as well.

Pig Crossbreeding:

A common strategy in Indian pig crossbreeding involves mating an exotic boar with an indigenous sow - for instance, crossing a Large White Yorkshire boar with Desi sows produces offspring reaching market weight considerably earlier than pure Desi pigs, while retaining much of the local breed's disease resistance. In the North-Eastern Hill region, which accounts for nearly half of India's pig population, indigenous Niang Megha pigs have been crossed with Hampshire boars (a US-origin exotic breed) to combine local adaptability with exotic productivity, with crossbred pigs of the desired exotic inheritance

level stabilized through inter se mating over six generations. As per the 20th Livestock Census (2019), India's pig population stood at 9.06 million, with indigenous breeds accounting for 79% of the total, and Assam leading the country in pig population, followed by Jharkhand and Meghalaya.

Poultry Crossbreeding (Backyard Poultry Improvement):

Unlike cattle and buffalo, poultry improvement in India has largely relied on selective breeding and synthetic-line development from exotic germplasm rather than direct crossing of exotic and native breeds in a fixed grading pattern, chiefly through the Project Directorate on Poultry (now ICAR-Directorate of Poultry Research, Hyderabad) and ICAR-Central Avian Research Institute (CARI), Izatnagar.

- Crossbred chicken varieties such as Gramapriya, Vanaraja, and Srinidhi have been developed using selective breeding of exotic germplasm and are being successfully propagated to rural and tribal backyards for sustainable production and incomes.
- Vanaraja - a dual-purpose variety developed by the Project Directorate on Poultry, Hyderabad, for free-range farming in rural and tribal areas; males weigh about 1.2–1.5 kg at 10 weeks, and females lay 120–140 eggs per laying year. It combines the indigenous Aseel breed with CARI Red genetic stock, producing active, larger-built birds.
- Kalinga Brown, Gramalakshmi, CARI Nirbheek, and other varieties similarly combine improved exotic genetic material with native fowl adaptability, developed largely from the 1990s–2000s onward.
- These programmes are distinct from commercial layer/broiler crossbreeding (using purely exotic strains such as White Leghorn and Cornish-Rock crosses), which follows international commercial breeding technology without indigenous germplasm involvement.

Crossbreeding Techniques Employed Across Species (Summary):

1. **Grading-Up (Absorption Crossing):**

   Repeated backcrossing of a nondescript/indigenous female line to an exotic sire line across generations, progressively increasing exotic inheritance - the dominant method in early cattle programmes.

2. **Fixed-Level Crossbreeding:**

   Stabilizing exotic inheritance at a target percentage (commonly 50%, 62.5%, or 75%) considered optimal for balancing productivity with adaptability, followed by inter se mating to "fix" the synthetic breed (e.g., Karan Fries, Frieswal, Sunandini).

3. **Two/Three-Breed Rotational And Terminal Crossbreeding:**

   Used more in sheep, goat, and pig programmes to exploit maximum heterosis for terminal (slaughter/market) generations.

4. **Synthetic/Composite Breed Formation:**

Combining more than two breeds systematically over generations to create a new stable breed (e.g., Avimaans from Dorset/Suffolk × Malpura/Sonadi).

5. **Artificial Insemination (AI) With Frozen/Deep-Frozen Semen:**

The principal technology enabling large-scale dissemination of exotic genetics, introduced through the Indo-Swiss Project (1963) as India's first application of deep-frozen semen technology.

Government Policy Framework:

Early Policy Instruments:

- **Key Village Scheme** (1950s) and Intensive Cattle Development Projects (1964) - the foundational national programmes for cattle genetic improvement.
- **Fourth Five-Year Plan** (1969–74) - formally endorsed crossbreeding as national dairy development policy.
- **Operation Flood** (1970 onward, NDDB) - while primarily a dairy cooperative and marketing initiative, it substantially expanded AI-based crossbreeding infrastructure nationwide.

Policy Correction Toward Conservation:

As productivity gains plateaued and concerns over indigenous breed erosion mounted, national policy pivoted toward conservation of indigenous genetic resources:

- National Bureau of Animal Genetic Resources (NBAGR), Karnal - established to characterize, register, and conserve indigenous livestock breeds.
- National Livestock Policy, 2013 - first comprehensive national policy explicitly emphasizing indigenous breed conservation alongside productivity enhancement.
- National Programme for Bovine Breeding and Dairy Development (NPBBDD), 2013, renamed the Rashtriya Gokul Mission (RGM), 2014 - the Government of India's flagship scheme for development and conservation of indigenous bovine breeds, covering 53 recognized desi cattle and buffalo breeds, administered by the Department of Animal Husbandry and Dairying (DAHD). Its three core objectives are development and conservation of indigenous breeds, genetic upgradation using elite indigenous bulls, and enhancement of milk production and productivity for small and marginal dairy farmers. Phase III (2021–26) has an outlay of ₹2,400 crore, later enhanced with an additional ₹1,000 crore, taking the total outlay to ₹3,400 crore for the 15th Finance Commission cycle, and emphasizes sex-sorted semen (with about 90% female-calf probability) and in-vitro fertilization to compress a decade-long conventional breed-improvement cycle into 4–5 years.
- Gokul Grams - integrated indigenous cattle development centres established to develop indigenous breeds, including up to 40% non-descript animals, with 20 Gokul Grams sanctioned across 13 states with an outlay of ₹197.67 crore.
- National Kamdhenu Breeding Centres - Centres of Excellence established to develop and conserve

indigenous breeds holistically and scientifically.

- National Gopal Ratna Award - instituted since 2021 to recognize farmers, dairy cooperatives, and AI technicians contributing to indigenous breed conservation.
- Rationale cited officially: Indigenous animals play a crucial role in the national economy through draught power, milk, organic manure (dung), and medicinal cow urine, and though crossbreds are more productive, they tend to underperform under low-input Indian conditions and harsh climate, with greater susceptibility to tropical diseases.

Species-Specific Coordinated Projects:

- All India Coordinated Research Project (AICRP) on Cattle (NDRI, Karnal - nodal centre) for crossbred cattle evaluation and breed development (Karan Fries, Karan Swiss).
- AICRP on Goats (originally CSWRI Avikanagar, later IVRI, Makhdoom).
- AICRP on Sheep for Wool (CSWRI Avikanagar) for Merino-based wool improvement breeds.
- AICRP on Pig for indigenous-exotic pig crossbreeding across agro-climatic zones, especially the North-East.
- AICRP on Poultry Breeding (CARI, Izatnagar; Directorate of Poultry Research, Hyderabad) for backyard poultry variety development.

Key Statistics (Livestock Census and DAHD/BAHS Data):

- Total bovine (cattle + buffalo) population: approximately 303 million as per the 20th Livestock Census (2019).
- Of the roughly 300 million cattle and buffaloes, about 191 million are cattle and 109 million are buffaloes; roughly 80% of total cattle are indigenous and non-descript breeds.
- Total indigenous (male and female, milking and non-milking) cattle population declined by about 6% to 14.2 crore, while exotic and crossbred cattle population grew by nearly 27%, reaching about 5 crore.
- Among milch cattle specifically, exotic/crossbred milch cattle grew by about 32%, from 1.9 crore to 2.5 crore - meaning foreign-genetic milch cattle now number more than half of desi milch cattle.
- The pace of decline in indigenous/non-descript cattle population (2012–2019) was markedly slower than the preceding period (2007–2012, 9% decline), suggesting that breed conservation programmes such as the Rashtriya Gokul Mission are having a moderating effect.
- Buffalo population: approximately 109.85 million, an increase of about 1.1% over the previous census, making India home to the largest buffalo population in the world.
- Pig population: 9.06 million (2019 census), with indigenous breeds forming 79% of the total.
- India's share of world livestock genetic diversity: around 20% for sheep, 33% for goats, and 16.5% for cattle, underscoring the global significance of conserving indigenous genetic resources against

further dilution.

Conclusion and Target of Ongoing Programmes:

The trajectory of livestock crossbreeding in India illustrates a characteristic arc from unplanned colonial-era experimentation, through intensive state-driven exotic infusion during the productivity-focused decades (1950s–1990s), to all more balanced, conservation-conscious policy framework from the 2010s onward. While crossbreeding delivered substantial, demonstrable gains in milk, meat, wool, and egg productivity - exemplified by breeds such as Karan Fries, Frieswal, Sunandini, Avimaans, and Vanaraja - it simultaneously accelerated the erosion of indigenous genetic diversity, adaptive traits, and disease resistance in several regionally important breeds. The current national target, articulated through the Rashtriya Gokul Mission and allied schemes, is not to abandon genetic improvement but to rebalance it: propagating high-genetic-merit indigenous bulls and sex-sorted/IVF technologies to raise indigenous breed productivity intrinsically, rather than relying solely on further exotic dilution - thereby safeguarding India's globally significant livestock genetic wealth while continuing to meet the nation's rising demand for milk, meat, wool, and eggs.

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