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NDDB-BAIF-NIAB-NBAGR 'Gau' and 'Mahish' SNP chips launched by Hon. Prime Minister Shri. Narendra Modi on October 5, 2024

Livestock Genomics for Smallholder Prosperity

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Cover Page Design:

Genome Technology has been introduced in BAIF programmes to ensure better evaluation of germplasm and for further breeding.

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Advancing Genomic Technologies for Sustainable Growth of Indian Dairy Sector

India's dairy industry holds a significant position as the largest milk producer globally. The sector is vital for the livelihoods of millions of smallholder farmers who depend on dairy farming for their primary income. India's dairy sector is marked by a wide variety of cattle and buffalo breeds, each suited to diverse environmental conditions. Indigenous breeds, known for their hardiness, typically have lower milk yield, while exotic breeds like Holstein Friesians, prized for their high milk production, often face issues of adaptability to local conditions. Crossbreeding has been a common practice to combine the advantages of both types. It has increased milk yield but has led to challenges in maintaining the desired genetic makeup.

Several issues hinder the growth and efficiency of India's dairy farming. The primary concern is the low productivity of livestock. Despite the country's dominance in milk production, the milk yield per cow is far behind global averages, which limits the profitability of dairy farming. The milk yield per animal is comparatively low, due to various factors such as genetics, inconsistent farming practices, feed and fodder deficiency and limited access to modern breeding technologies. This is compounded by fragmented landholdings, with most farmers operating small-scale farms and having limited access to tools for efficient breeding and management. Climate change has also posed additional challenges in terms of heat stress on animals, epidemics like lumpy skin diseases and fodder scarcity.

The genetic composition of crossbred cattle can be difficult to determine especially when pedigree records are incomplete or inaccurate. The genetic recombination caused by meiosis during reproduction often leads to variations in the genetic makeup of the next generation, making it hard to predict and therefore difficult to optimise livestock performance. Indiscriminate crossbreeding may reduce the resilience of livestock to environmental stresses such as heat and diseases. Adoption of advanced breeding technologies such as genetic testing has been slow, largely due to their high cost. For most smallholder farmers, who make up the majority of the dairy sector, these technologies are financially inaccessible, making them depend on breeding methods which are slow and less effective.

Genomic technologies offer significant potential for transforming India's dairy industry. One of the most promising advances is genomic selection, a method that uses DNA markers (SNPs) to predict genetic potential of animals for various economic traits, at a very early age, well before the animals reach maturity. This allows farmers to make breeding decisions that would traditionally take years. Genomic selection can provide a much faster and more accurate way to improve economically important traits such as milk yield, fertility, disease resistance and feed efficiency.

On October 5, 2024, Hon. Prime Minister Shri. Narendra Modi launched the 'Unified Genomic Chip', the 77K SNP 'Gau' chip for cattle and 60K SNP 'Mahish' chip for buffaloes. These SNP chips designed for genomic profiling and evaluation of Indian cattle breeds, have been developed by a consortium led by the National Dairy Development Board and comprising of BAIF, National Institute of Animal Biotechnology and the ICAR-National Bureau of Animal Genetic Resources. Each participating organisation pooled their whole genome sequence and genotype data to facilitate the development of these genomic techniques. These specialised chips will allow accurate prediction of genetic merit of the animal and enable farmers to take better breeding decisions. With these sustainable tools, farmers can enhance milk production, maintain animal health and ensure better adaptability to local conditions.

BAIF and allied research partners concluded that breed composition does have an impact on productivity of crossbred cows reared under different production systems. This led to a more affordable genetic test – building small SNP panels to enable farmers to assess the genetic makeup of their animals even when pedigree records are lacking or unreliable.

Farmers can identify the right mix of indigenous and exotic genetics in their herds, optimising both productivity and environmental adaptability. These technologies also offer a more accessible alternative to comparatively expensive genetic tests.

To fully realise the potential of genomic technologies in the dairy sector, a few major steps are necessary. First, there needs to be wider access to genomic selection tools. This should start from adoption of this technology by breeding organisations and institutes to select and produce superior germplasm. BAIF has already initiated selecting and producing genetically superior animals using genomic selection in combination with advanced reproductive technologies like sex sorted semen and in-vitro fertilisation – embryo transfer. BAIF is also facilitating the state departments through capacity building. The affordability and accessibility of the product of these technologies must be ensured, especially for smallholder farmers, who form the backbone of India's dairy industry. These efforts will also require farmer awareness programmes for better adaptability of these advanced technologies by smallholder farmers. Innovative financing models will have to be created for easy access by small-scale farmers. Genomic evaluation programmes need to be expanded to multi-breed and multi-trait characteristics while creating a large reference population. The success of genomic selection depends on large reference populations for accurate predictions. The current size of such populations in India is still limited. Expanding these reference populations among the consortia partners will not only increase the accuracy of genomic predictions but also help to make breeding decisions more effective. The inclusion of genotype and environmental interactions in genomic evaluation is another important step to ensure that genomic tools are comprehensive and useful for dairy farming.

Overcoming logistical challenges such as internet connectivity and mobile access in rural areas will also be crucial. Developing user-friendly platforms for farmers and field staff to collect and access data will enable the broader implementation of genomic technologies, even in the most remote areas. Training and capacity building are also necessary to ensure that all stakeholders, including farmers, veterinarians and technicians, are capable of handling and making best use of these tools.

The livestock management programme of BAIF has been able to reach out to 3.5 million families from 100,000 villages in 343 districts of 13 states through genetic improvement of livestock, preventive healthcare and feed management. 7.36 million cows and buffaloes born under the programme are in milk, yielding 8.72 million tons per annum. This has had a multiplier effect on the productivity of the animals, gain in income of smallholders and protein supply to the consumers. This programme in close association with the State Governments, results in better animal health and reduction in methane emission. The by-product - dung, goes back to the soil and improves the crop productivity. Thus, crop-livestock system brings in an integrated, holistic and circular economy approach by addressing resilient livelihoods as well as mitigation. BAIF has been able to contribute 234 billion to the rural economy during the financial year 2023-24 and has enabled smallholders to come out of poverty and earn their livelihood. With the support of Bill & Melinda Gates Foundation, BAIF has contributed to the development of two chips which will help in enhancing its genetic enrichment programme in India.

In conclusion, the integration of genomic technologies with India's dairy sector holds immense promise for the future. By making breeding decisions more accurate, efficient and timely, genomic selection can significantly boost productivity and enhance the health of dairy livestock. Technologies such as small SNP panels and customised SNP chips can help optimise herd management while preserving the resilience of cattle to environmental challenges. Through financial models that increase accessibility, the adoption of these tools can be widespread for the benefit of smallholder farmers.

While challenges such as improving infrastructure, expanding genomic databases and ensuring large-scale adoption remain, the path ahead is clear. Continued investment in research, development and training and collaboration between public and private stakeholders, will help India's dairy sector unlock its full potential. By harnessing the power of genomics, India can build a more productive, resilient and economically viable dairy industry, supporting the livelihoods of millions of farmers and securing the country's position as a global dairy leader.

Dr. Bharat Kakade
President and Managing Trustee, BAIF

Genetic Improvement of Cattle and Buffaloes: How does it work?

Vincent Ducrocq, Ben Hayes and John Gibson

More than 50 years ago, North American scientists realised that choosing the best bulls based on their looks was rather inefficient. To improve milk production, they showed that farmers should systematically use artificial insemination using the "best bulls", sons of the "very best" bulls and cows. To select these best bulls, it was necessary to wait till the end of the first lactation of 50 to 100 of their own daughters. This was called "progeny testing". If on an average, the daughters of a bull had a very good milk production with high fat and also a good udder, good feet and legs, a good fertility, etc, the semen of these progeny tested bulls was used to inseminate the rest of the cows. The other bulls with progeny with low production or poor conformation were discarded and so was their stored semen. The daughters born from a bull under progeny testing finished their first lactation when their father reached 6 or 7 years of age. It was only then that the Artificial Insemination companies could decide on keeping and using their best bulls and getting rid of all the others.

In 2001, a scientific article of an Australian team[1] completely revolutionised genetic selection: they showed that on each chromosome which carries the genome of any animal, there are many "markers" called SNPs - where DNA exists in 4 distinct forms, just like an alphabet with only 4 letters. Thousands of these SNPs are easy to collect together at a relatively low cost for any animal, analysing for example a blood sample. This is called "genotyping". Determining the SNPs of a particular animal is very useful: all the SNPs together are like an ID card and they can be used to predict the characteristics of a young calf or even an embryo. This is easy if the trait is simple (to determine skin colour for example) but it needs more information and more work if the trait is very complex – such as milk yield, fat production, udder conformation or resistance to mastitis, etc. In such cases, it is necessary to first create a "reference population" i.e. a group of cows as large as possible for which we know their markers (the SNPs) as well as their actual milk yield, fat yield, udder conformation and mastitis occurrence. This reference population plays the role of a dictionary with which we can interpret the SNPs of any genotyped young male or female. Then, we know almost at birth how good these young males and females are, at a reasonable cost compared to the genetic selection case.

[1] *Prediction of total genetic value using genome wide dense marker maps* - Theo Meuwissen, Ben Hayes and Mike Goddard

The views expressed in this article are those of the authors.

Genomic selection was quickly adopted in North America, Europe, Australia and New Zealand. Initially, genotyping was relatively expensive and above all, it was observed that the size and the quality of the reference populations had a huge impact on the accuracy of genomic selection. This is why for example in France, 4000 Holstein progeny-tested bulls were genotyped first. But quickly these genotypes were shared with genotypes of bulls of other European countries (Germany, Holland, Spain, Denmark, Sweden and Finland). So, without extra costs, the global reference population of these countries quickly reached 16000 genotyped AI bulls in 2010 and 38000 bulls and 3.7 million genotyped cows in 2023. Farmers from countries with large reference populations are now quickly improving their cows through artificial insemination for a large number of complex traits such as female fertility, udder shape and resistance to mastitis on top of milk and fat production.

Small breeds also developed their own reference population. In France, as an extreme example, the *Vosgienne* breed had less than 5000 cows: the breed was going to disappear because bulls under progeny-test were very few (2-3 per year) and quite inbred. With genomic selection, this breed is now safe and improving.

In India, with strong support from the Bill & Melinda Gates Foundation, BAIF started the creation of separate reference populations a few years ago: first, one for crossbred cattle (essentially, Holstein and Jersey crosses with zebu and "non-descript" breeds), then one for pure zebus and one for buffaloes in a dozen Indian states. This is a complex and expensive task, especially when the average herd sizes are small. The current work is quite promising and a few thousand cows have been genotyped on several major traits.

In practice, taking French Holstein as an illustration, each of the two major French Artificial Insemination (AI) companies selects around 3000 heifers at birth among the best genotyped ones in the country. A year and a half later, after updating their genomic evaluation, the top 700 of these heifers are retained to generate (via superovulation) 3000 male embryos which are genotyped at birth. The 80 best males are sent to the AI stud farm where they produce semen between 10 to 18 months of age.

Clearly, such a design is nearly impossible to envision in India. But it illustrates that genomic selection "only" requires -

- A large enough reference population representative of the dairy system, including rigorous data collected on farm.
- The choice of the best young bulls and best first or second lactation cows based essentially on their estimated genotype.
- A very rapid turnover of the selected animals.

Vincent Ducrocq, INRAE, France, Ben Hayes, University of Queensland, Australia and John Gibson, University of New England, Australia, are associated with BAIF in the Enhanced Genetics Project (EGP) as Technical Advisory Group members .

Using Genomics to improve Crossbred Dairy Cattle for Smallholder Farmers

John Gibson, Ben Hayes and Vincent Ducrocq

Some 37 million crossbred dairy cattle are milked in India and most of them are in smallholder herds. As described in the previous article in this magazine, the new genomic technologies can be used to drive genetic improvement in all dairy cattle and buffaloes. But crossbred cattle have some particular complexities and special needs that genomic tools are especially helpful in solving.

Crossbreeding of indigenous and exotic dairy cattle has been taking place in India for well over 50 years. In some parts of India, crosses are mostly of Holstein-Friesians to indigenous cattle, while in other parts, crosses are mostly between Jersey and indigenous cattle. While it is generally accepted that many smallholder dairy systems benefit from use of crossbred cows, and that pure exotic breeds do not thrive in these conditions, it is not known exactly what type of crossbred is best for a given smallholder production environment. Most crossbred cows result from the breeding of existing crossbred cows to either pure exotic or crossbred bulls. Since most farmers do not keep detailed breeding records, the breed composition of most crossbred cows today is not known. So, it is not possible to say what is the best type of bull to mate with a given cow because the breed composition of the cow is not known and it is also not known what is the most desirable composition for a female calf she produces in a given farm.

SNP assays can help solve this problem. The SNP assays that have been designed for use in India give results for the genotypes of over 60,000 SNPs for each cow that is tested. By comparing a cow's genotypes for these 60,000 SNPs with those for exotic and indigenous breeds of cattle, it is possible to determine how much Holstein-Friesian versus Jersey versus indigenous breed ancestry that cow has inherited. By genotyping cows that are recorded for their performance in the BAIF Enhanced Genetics Project (EGP), it is possible to relate the breed composition of cows to their performance. Eventually, when sufficient data has been collected, it will be possible to determine which breed composition performs best in a given environment.

But in order to advise a farmer what is the best breed composition of bulls to use to produce the next generation of cows, the farmer needs to know the breed composition of each cow. The 60,000 SNP assay is quite expensive. It is too expensive for most farmers to use for testing their cows. So,

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Crossbred bulls produced by BAIF are used to breed crossbred cows, to optimise the breed composition of replacement cows.

BAIF and collaborators have undertaken research that has found just 500 SNPs that are predicted to give nearly as accurate an estimate of breed composition as the 60,000 SNPs. This has allowed BAIF to team up with ThermoFisher, a genomic testing company, to develop and test a much smaller and cheaper genomic, of just 500 SNPs, that could be used by farmers for routine testing of their cows. The initial results on some 600 cows show that the new assay is, as predicted, highly accurate. A full validation trial will be undertaken soon. As each cow only needs to be tested once in its lifetime, this new assay is expected to give farmers a cheap and effective tool to ensure that they produce offspring of the best breed composition for their farm, by using a bull that has the most appropriate breed composition.

While crossbreeding has been successful in combining the milk production potential of some exotic breeds with the hardiness of indigenous breeds, there has not been ongoing genetic improvement of crossbreds. That is because the exotic bulls descend from bulls that were imported and these bulls have been genetically improved for purebred Holstein-Friesian or purebred Jersey production in intensive, temperate dairy systems and not for crossbred production under Indian smallholder conditions. The BAIF EGP is delivering for the first-time genetic improvement of both purebred exotic and crossbred bulls for the performance of their crossbred progeny. The same genomic approach is being used as described in the previous article. But in the case of crossbreds, some additional complexities had to be solved.

Firstly, we know in addition to a bull's own genetic merit, the breed composition of the progeny will affect the crossbred progeny's performance. Secondly, different types of crossbreds are expected to produce differently in different environments. For example, in an intensive environment with excellent feed and disease control and a mild climate, we expect high-grade exotics will do well. While in poor environments with low quality feed, high disease exposure and a hot climate, we expect high-grade exotics to fail and high-grade indigenous animals to perform best. So, we need to account for both the breed composition and the environment and their interaction, when estimating the genetic merit of animals.

Again, genomics provides the solution to this problem. In addition to determining the relationship among all animals in the population, which is required to estimate genetic merit of animals and select the best breeding animals, the SNP assay provides an estimate of breed composition, as described above. We can then perform genetic analyses that consider the genetic relationships among animals and their breed composition and also account for the environment in which each cow performs.

The BAIF EGP has already demonstrated that it is possible to estimate the breeding values of individual animals and to determine the performance of different types of crossbred cows in different environments. This has already allowed BAIF to improve the genetic quality for milk production of the bulls that are offered for AI. The EGP is generating large amounts of new data that will allow more accurate estimation of genetic merit and breed composition effects for a range of important production characteristics such as milk production, milk composition and body size. New traits such as heat tolerance are also being explored. This will allow BAIF and other agencies to deliver continuous genetic improvement of crossbred cattle, for the benefit of smallholder farmers across India.

John Gibson, University of New England, Australia, Ben Hayes, University of Queensland, Australia and Vincent Ducrocq, INRAE, France, are associated with BAIF in the Enhanced Genetics Project (EGP) as Technical Advisory Group members.

Genomic test to determine breed composition of crossbred cows with complex and undocumented ancestries.

Potential and Economic Impacts of Genomic Selection for Dairy Cattle and Buffalo Improvement in India

Nilesh Nayee, Swapnil Gajjar, Sujit Saha,
Atul Mahajan, A. Sudhakar and K. R. Trivedi

Breeding of dairy cattle has travelled a long way from initial days of daughter-dam comparisons to recent advances in Genomic Selection. However, the progress has been backed up by sound performance recording infrastructure and use of Artificial Insemination for breeding cows. India, the largest milk producing nation with huge bovine population, has been treading this path at a slower pace.

Performance recording systems: Farmers consider their animals as family members and have a mental map of each animal. Hence, they do not think it is necessary to maintain individual animal record of just 2-3 animals owned by them. Moreover, the country has a huge diversity in terms of species and breeds being used, the purpose of keeping cattle and buffaloes, management practices, feeding pattern and agroclimatic conditions. This poses a huge challenge for agencies working towards genetic improvement and Artificial Insemination in bovines.

However, the country is managing to overcome these challenges. Relatively larger performance recording programmes are now implemented, for various cattle and buffalo breeds having milk production potential. Progeny Testing and Pedigree Selection projects are being funded under the centrally sponsored Rashtriya Gokul Mission Scheme. With the recent announcement of National Milk Recording Programme, a greater number of animals in different areas is being recorded.

Initial performance recording was focussed on collecting data on milk volume of the animals. There was a wide variation on trait definition and recording practices. Standard Operating Procedures and Minimum Standards are being administered in the programmes to maintain quality and uniformity in data collection and estimation.

Genetic and genomic evaluation systems: Progeny Testing for selection of bulls was an industry norm for a very long time across the world. However, smallholder farming system, lack of data aggregated at a central level, scattered population and long generation interval made Progeny Testing-based bull selection a non-viable approach.

Starting from early 1970s, organisations made sporadic efforts to implement Progeny Testing. After some small-scale experiments from 1989, NDDB under National Dairy Plan I, in collaboration with

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various agencies, started pan-India networks for production of young bulls based on this approach. A system of selection of bull sires based on progeny testing and using it to produce young bulls from elite cows "Young Bull Progeny Testing Model", was implemented and the approach is being continued under Rashtriya Gokul Mission.

However, there are many breeds which are important for National AI programmes but lack Progeny Testing Network due to scattered population and apathy of agencies to record data and to ensure follow up. Due to lack of deep pedigrees, estimation of genetic parameters and accurate ranking of bulls was a big challenge. Selection of bulls based on Dam's Lactation yield was of questionable genetic merit leading to slower genetic progress. Limited number of bulls put to test under Progeny Testing projects always limited the accuracy of ranking of bulls based on pedigree data.

Genomic Evaluation and its impact: Genomic Selection revolutionised the dairy breeding industry. Newer approaches to fast track genetic progress in various populations were tried out. Various research articles pointed out the feasibility of implementing genetic improvement programmes even in the populations where large-scale Progeny Testing was not feasible. Researchers showed value of adding genotypes of recorded females in the reference population to increase accuracy of genomic evaluations. Younger bulls started being used in the Artificial Insemination programme to fast track genetic progress.

This shift in breeding strategy was perceived as a boon and various agencies such as National Institute of Animal Biotechnology (NIAB), Hyderabad, National Bureau of Animal Genetic Resources (NBAGR), Karnal, BAIF Development Research Foundation, Pune and National Dairy Development Board (NDDB), Anand, made efforts to implement genomic selection in Indian dairy populations.

NDDB's efforts were focussed on developing a reference population for enabling genomic evaluations in the breeds that are important for frozen semen production for the national Artificial Insemination programme. Biological samples were collected from animals that were under systematic performance recording. Commercial genotyping solutions were customised for developing panels useful for all important cattle breeds. Sequencing efforts developed a genotyping panel for buffaloes.

In 2016-17, the first genomic evaluation was approved by the Breeding Value Estimation Committee, Government of India and the approach was introduced in the bull production programme.

So far, national genomic evaluations are in place for three indigenous breeds - Gir, Sahiwal and Kankrej, two crossbred breeds- Jersey Crossbred and Holstein crossbreds with Indicus breed and two buffalo breeds - Murrah and Mehsana. The genomic evaluations were incorporated in breeding programmes that are a source of bulls for frozen semen production. The cows under the recording programme are evaluated based on their performance records, pedigree information and genotype data (if available) and ranked based on their Estimated Breeding Values (EBVs) / Genomic Breeding Values (GBVs). Top 5-10% cows are used as bull mothers. Bulls used as sires of sons based on their EBVs/GBVs and design mating are organised to produce double the bull calves required as replacement bulls for the breeds.

All the bull calves are genotyped and included in genomic evaluations that are conducted every week. Based on the requirement of bulls across semen stations, cut-off value for GBVs are decided for each breed. The GBV cut off is revised each year based on advanced demand for the next year from semen stations. Bull calves having GBVs above cut-off value, negative for various genetic defects, free from various contagious and zoonotic diseases as notified under Minimum Standards for Frozen Semen production in India and conforming to the breed characteristics, are procured from farmers at a very young age. The bull calves are quarantined and tested and once cleared, are distributed to semen production centres across the country.

Validation studies showed that genomic breeding values are 4-6 times more correlated with the bull's daughter's performance compared to the Dam's lactation yield. This indicates that a genomic approach will fast track genetic progress of animals under Artificial Insemination in the country. Reliabilities for young bulls are ranging from 0.25 to 0.45 based on breeds involved, size of reference population and degree of relationship of young bulls with the reference population. With around 600-800 bulls being replaced each year for the breeds under genomic evaluations, this approach will have immense impact on productivity of bovines.

Though there is a sizeable exchange of animals across the country for various breeds, most of the times, the animals are purchased and sold locally. In a country like India with varied agroclimatic conditions and different managemental practices, it is interesting to perceive that there will be a huge G x E and ranking of bulls based on reference population of one area may not be suitable for another area. However, the validation studies indicate that there are reasonable correlations between bulls' GBV estimated on reference population recorded in one area and daughter's performance recorded in another area. This has encouraged adoption of genomic selection of bulls for use in semen stations.

Future perspectives: The size of the reference population is still a limiting factor for achieving higher reliabilities for genomic evaluations. With limited recording programmes, difficulties in collection of samples and limited population size in certain breeds like Red Sindhi, we are not able to include all the breeds important for frozen semen production in the country. With current selection programmes, primarily focussing on milk production traits, there is a possibility of compromising on the progress in other traits. The recording programmes have started recording for Fat% and Protein% and genomic evaluations are available for these traits in most of the breeds. With reproduction data being recorded in some of the projects, there is also scope for implementing genomic evaluations for reproduction traits in certain breeds. However, the standards enforced at present do not allow ranking based on composite index.

Since recording programmes are limited, the entire variability in a specific breed may not be fully represented in the reference population. This may limit reliabilities in some of the animals evaluated. This can be overcome by increasing the reach of recording programmes in most of the areas where the breed is prevalent.

As high as 25% of the frozen semen doses used in the country are from pure HF and Jersey breeds. Many of the bulls or semen doses are imported from Germany, Denmark, USA and Canada. There is also a sizeable population of cows that can be categorised as Indian Holstein in various parts of the country. Hence, performance recording programmes in such populations is worth considering to create an Indian genomic reference for Holstein cattle. Considering a very large difference in managemental practices as well as climatic conditions, the GBVs for Holstein based on foreign reference population may not be relevant in average Indian conditions.

Jersey and other breeds with lesser number of animals under recording programme still remain a challenge. It may be worth trying multi-breed genomic evaluation approach for such breeds. Some approaches involving meta founder may be tried including some of the Bos Indicus breeds, Bos Taurus breeds and crossbred data. However, research evidence to showcase consistent performance of such models is yet to be accumulated.

Traits such as mastitis resistance or low Somatic Cell Count, feed efficiency, GHG emissions and Tick resistance should be included in selection programmes. However, the real challenge is the feasibility of recording a large number of animals for such traits in smallholder conditions. Including various organised herds along with field animals in collecting phenotypes for these traits, may be an option.

Educating farmers, Artificial Insemination technicians and veterinarians involved in breeding services on potential benefits of genomic evaluation, is another challenge. Genomic evaluation in India has created an opportunity for faster genetic improvement on various traits. However, challenges posed by large variations among and within breeds, smallholder conditions and extension services for farmers need to be addressed for successful breeding programmes.

Nilesh Nayee, Swapnil Gajjar, Sujit Saha, Atul Mahajan, A Sudhakar and KR Trivedi - Scientists at National Dairy Development Board, Anand.

Digitising Phenotype Data Collection for Genomic Selection

Yuvraj Gaundare, Kaustubh Bhave, Tejashree Shirsath and Nikhil Punde

Introduction

A systematic breeding programme is a pre-requisite for improving the genetic qualities of the animals. Hence, collecting the data on animal performance, reproduction and health and evaluating those data for identifying animals with better genetic qualities plays an important role. BAIF has promoted advanced technologies to digitalise data collection for genomic evaluation for the benefit of breeders and farmers in tracking animal performance and improving breeding strategies through genomic selection.

Phenotype Data Collection

Phenotype data refers to information on physical characteristics and performance of an animal such as milk yield, milk quality parameters, body weight, fertility performance, milking temperament and incidences of disease. This enables better decisions on breeding, feeding and general management of livestock.

Earlier, information recorded manually by Artificial Insemination Technicians (AITs) and Performance recorders led to poor data quality.

Digital Field Data Collection System developed by BAIF: To overcome these challenges, BAIF has developed a online and platform-independent field data collection software solution that helps farmers and field staff to record data quickly and accurately. BAIF has created an enabling system to work on mobile phones, tablets or computers thereby making it easy to use in remote rural areas and to collect information on milk production characteristics, breeding, feeding, disease, height, weight and body condition in a structured way. Thus a large database of animals is created which can be used for farm management decisions and genetic evaluation.

Enhanced Genetics Project Console: Central hub to monitor data collection.

Field Performance Recorder's Console: Field workers known as enumerators use this console to collect the milk yield data. The system also supports Bluetooth-enabled milk analysers.

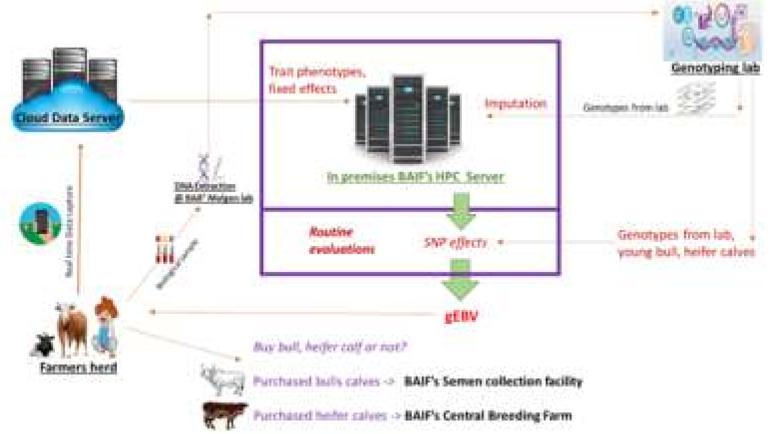
Molecular Biology Laboratory Console: When biological samples such as blood are collected from animals, the lab technicians record the information in the system.

Livestock Development Centre Console: Staff stationed at livestock development centres use this console to track Artificial Insemination, natural mating, pregnancy detection and calving records.

Farmers' Console: Farmers can enter milk yield, feeding pattern and health record.

Ensuring Accuracy and Validity: BAIF's system has built-in features such as GPS-Enabled Data Entry, Validation Checks and Bluetooth-enabled milk analysers.

Data Management Systems: The data is stored on a secure cloud platform, ensuring that it is easily accessible and safe.



Overall systematic flow and infrastructure developed by BAIF for performance data recording and Genomic Selection analysis

User-Friendly Interfaces: Simple interfaces allow farmers and field staff to enter and access data.

Automated Monitoring: Supervisors and administrators can monitor the data collection process in real-time, ensuring that the data is accurate and timely.

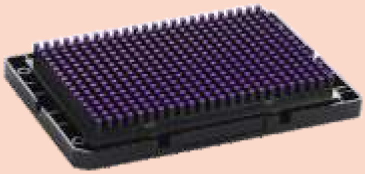
High-Performance Computing Infrastructure: BAIF has developed a high-performance computing (HPC) infrastructure which processes the data collected from the field, performing complex analyses to identify genetic traits in animals and providing access to Network Attached Storage of genotyped and whole genome sequenced data for future analysis. Storage of Bioinformatics Tools facilitates recommendations for breeding programmes and genomic evaluation analysis.

Benefits for Smallholder Farmers: This technology helps to identify animals with superior genetics and breed better animals. Farmers and field staff may need training on how to use the system effectively. BAIF has designed the system to work with 2G internet speed as well to ensure that data can be entered and synchronised real-time.

Way Forward

BAIF's digital field data collection system is helping farmers to improve the productivity and health of their animals. Through genomics-based breeding and data-driven decision-making, smallholder farmers can now manage their herds more efficiently. BAIF aims to expand this system to include more regions and more animals. The long-term goal is to create a large, diverse reference population that will be used for genomic selection. BAIF has developed a platform-independent application that can work on any smartphone or tablet, to enable farmers to participate in the programme.

Yuvraj Gaundare, Kaustubh Bhave, Tejashree Shirsath and Nikhil Punde are a part of the Livestock Genomics team at BAIF Central Research Station, Uruli Kanchan.



Development of SNP Microarrays for Genomic Profiling of Indian Cattle and Buffaloes

Santoshkumar Jadhav and Sachin Joshi

In the last two decades, technologies developed for genome sequencing and genotyping, have identified the markers on genome sequences. Markers are located on genome sequences and a few markers are close to economically important genes or Quantitative Trait Loci (QTL). These markers influence milk yield, quality, disease resistance and body characteristics.

Molecular markers are important tools often used in biotechnology applications and especially in breeding programmes. The most popular are Single Nucleotide Polymorphism markers (SNPs) for genetic mapping, identification of QTLs responsible for sex determination, parentage verification, chromosome manipulation experiments and genomic selection. As commercial SNP chips provide more information on exotic breeds, it is necessary to customise SNP arrays for Indian breeds.

India is home to 53 well-characterised cattle breeds and 20 buffalo breeds. To improve the milk yield, quality traits and disease resistance of these breeds, development of SNP chips specifically tailored to Indian cattle and buffalo breeds help farmers to understand the breed composition of their animals. Additionally, farmers increasingly seek to understand the breed composition of their animals. SNP chips facilitate the identification of cross-breed and indigenous breed proportions. It also identifies parent-offspring trios and in calculating Genomic Estimated Breeding Values (GEBVs). The resulting breeding values, expressed as positive or negative, guide the selection of animals for breeding programmes aimed at improving desirable traits. 77K SNP chips have been developed for cattle and buffalo breeds under a consortia of NDDB, NIAB, NBAGR and BAIF of which 60K SNP chips were released for use by breeding organisations and researchers in bovine breeding programmes.

Santoshkumar Jadhav and Sachin Joshi are Livestock Geneticists at BAIF Central Research Station, Uruli Kanchan.

Development of small SNP Panels – A tool for Genetic Management of Crossbreeding Programme

Velu Dhanikachalam, Akshay Joshi and Vinod Potdar

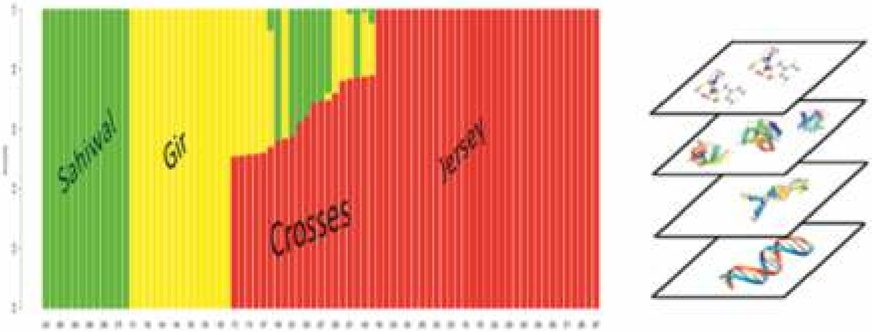
In India, crossbreeding exotic cattle breeds with non-descript animals has become a critical strategy for enhancing livestock productivity, especially in the smallholder dairy production system and organised dairy sector. This approach combines high milk producing exotic breeds such as Holstein Friesian, Jersey and Brown Swiss with the resilience and adaptability of local indigenous breeds and non-descript cattle suited to India's diverse environmental conditions. This not only increases milk production but also supports the livelihoods of small-scale farmers.

Practical Challenges in Crossbreeding

Maintaining the desired percentage of exotic inheritance, such as 50% or 75%, is essential in crossbreeding programmes to balance the high productivity of exotic breeds with the adaptability of native breeds. However, several challenges complicate this process, particularly improper record-keeping by farmers and breeders. In many smallholder farms across India, systematic pedigree data is often not maintained, making it difficult to accurately track the breed composition of exotic and native animals. Without reliable pedigree information, the actual percentage of exotic inheritance may become unclear, hindering the ability to optimise livestock performance and achieve the intended breeding goals.

Additionally, meiosis, the process of forming gametes, introduces genetic variation. During meiosis, chromosomes are randomly shuffled and genes are recombined, leading to different combinations of genetic material in the offspring. As a result, offsprings may differ in proportion of exotic or indigenous genes than expected, causing variation. For instance, while the goal may be to maintain 50% exotic inheritance, some offsprings may inherit slightly more or less due to this random segregation. Over time, this variability can affect the uniformity of traits like milk production or adaptability if not carefully managed.

Continuous crossbreeding without careful management can gradually shift the genetic composition toward a higher proportion of exotic genes. If crossbreeding is carried out indiscriminately, the offspring may inherit a higher proportion of exotic levels which may not be desirable in terms of adaptability under Indian conditions. Higher levels of exotic breed proportions are less adapted to India's tropical climate, diseases and low-input farming systems. As the genetic



Admixture Analysis

makeup shifts toward the purity of exotic breeds resulting in the alteration of resilience traits of native cattle such as heat tolerance and disease resistance, the animals become susceptible to environmental stresses and their survival and suitability to local conditions are threatened.

Affordable Tests for Breed Composition

The breed composition of crossbred cattle can be accurately determined using genetic markers such as Single Nucleotide Polymorphisms (SNPs). However, the existing SNP arrays remain expensive for large scale use in smallholder dairy systems in developing countries. Hence, affordable alternatives are needed to make genetic testing more accessible and to promote sustainable crossbreeding efforts.

To address this, Strucken *et al.*, 2021(DOI:10.1111/jbg.12544) developed affordable low density SNP markers to analyse the genetic makeup of cattle in India. These tests identify the combination of indigenous and exotic breeds, helping small-scale farmers to make breeding decisions even when pedigree records are unavailable. This innovative approach improves milk yield, enhances herd resilience and ensures adaptability to local climate, thereby promoting sustainable livestock management.

These affordable SNP-based tests make genomic testing more accessible and help smallholders to enhance their milk yield and improve herd resilience.

Conclusion

Small SNP panel-based breed composition analysis provides affordable genetic insights and thus enables farmers to make informed breeding decisions that can enhance productivity and sustainability. This approach optimises milk yield while ensuring better adaptation to local environmental conditions. Thus, small panel interventions can strengthen the dairy sector in the country. By integrating advanced genetic testing with traditional farming practices, the farmers can enhance their herds and contribute to sustainable dairy development in India.

Velu Dhanikachalam, Akshay Joshi and Vinod Potdar are a part of the Livestock Genomics team at BAIF Central Research Station, Uruli Kanchan.

Genomic Selection in Indian Dairy: Exploring Economic Viability and Financial Models for Empowerment

Shrinivas Kulkarni

Background

The Indian dairy sector, the cornerstone of the rural economy, supports the livelihoods of millions of smallholder farmers. While India is the largest milk producer globally, it continues to grapple with low productivity per animal. This challenge stems from factors such as extensive genetic diversity, fragmented farm structures and limited access to advanced breeding technologies. Addressing these issues is crucial for boosting productivity, ensuring food security and increasing farmers' incomes. In this context, genomics-based genetic improvement technologies in dairy breeding emerges as an opportunity to address these challenges effectively.

Promotion of Genome Technology

Genomic selection as a part of a comprehensive and systematic genetic improvement programme, can transform breeding practices by using genomic information to predict the genetic merit of breeding animals for milk yield, disease resistance and fertility. By making data-driven and systematic breeding choices, farmers can achieve more productive herds and healthier livestock. BAIF focusses on practical solutions that directly impact farmers' lives. Genome technology is an important step in this effort. For years, BAIF has focussed on increasing livestock productivity through Artificial Insemination with both conventional and sorted semen and embryo transfer programmes which have given a boost to genetic potential across India. BAIF is in collaboration with NDDB, NIAB and NBAGR on a consortium-driven genomic selection project with the support of Bill & Melinda Gates Foundation. The release of the 'Gau' and 'Mahish' chips, by the Prime Minister of India, showcases the efforts of research institutions, policy makers and the scientific community to advance the genetics of Indian cattle and buffaloes.

Genomic Chips: A Step Forward with Practical Value

The 'Gau' and 'Mahish' chips designed for indigenous breeds, provide farmers with practical, cost-effective genomic tools. These chips are research milestones and steps towards integrating precision breeding with routine dairy farming.

Using Predictive Genomics for Targeted Breeding

While genomic selection has traditionally been in the research phase, the recent launch of the 'Gau' and 'Mahish' chips and related genetic analytical capabilities, signals significant progress towards practical application. These advancements enable farmers to consider more precise breeding decisions with better insight into traits like milk yield and disease resistance. To start with, this technology can be used to identify elite bulls for semen production and select high-value bull mothers for breeding and embryo transfers, aiming to strengthen herd quality and accelerate genetic improvement.

Financial Pathways for making Genomic Technology Accessible

The solution lies in developing inclusive financial models that distribute the costs and ensure long-term sustainability.

1. **Public-Private Partnership (PPP):** One of the most effective ways to fund genomic selection programmes is through public-private partnerships. The government can play a significant role by providing subsidies or tax incentives for genomic evaluation infrastructure, especially in rural areas where access is limited. Private companies and institutions, particularly those involved in dairy, animal breeding and health, can invest in genetic research and development, knowing that the resultant improvements will benefit the entire dairy supply chain.

   BAIF's partnerships with government agencies, private organisations and global institutions like the Bill & Melinda Gates Foundation show the effectiveness of this model whereby we can distribute the financial burden and ensure that genomic selection programmes are not limited to only large farms or corporate-owned dairies.

2. **Cooperative cost sharing model:** In India, cooperatives have played a vital role in the growth of the dairy sector. These cooperatives can act as local collection centres where farmers bring data and samples for analysis. These samples are then sent to central laboratories for genomic testing. Farmers can pay a nominal fee to their cooperative for access to genomic tools and services. This approach ensures that no single farmer bears the burden of the entire cost while making technology accessible to those with limited resources. BAIF has successfully worked with cooperatives to implement various programmes. By organising these programmes at the cooperative level, we can ensure fair distribution of costs and benefits.

3. **International Grants and Philanthropic Support:** International organisations such as the Bill & Melinda Gates Foundation have shown keen interest in supporting genomic selection in agriculture. BAIF's genomics research is being largely funded by the Gates Foundation. This type of philanthropic support can cover the initial investments needed for infrastructure and research, making it possible to scale these programmes quickly across the country.

Chip development is a clear example of how international and domestic support can lead to breakthroughs in genomic technology. These partnerships have accelerated research and also made the resulting products and services more affordable for Indian farmers.

4. **Microfinance and Livestock Insurance:** Smallholder farmers often struggle with high upfront costs. Low-interest microfinance loans specifically designed for livestock improvement can enable these farmers to invest in genomic technology. Livestock insurance provides financial protection against disease or loss of valuable animals, encouraging farmers to adopt new technologies with confidence.
5. **Subscription-Based Models:** A multi-level subscription system allows farmers to pay regular fees for genomic testing and support services and scope for participation. This model provides continuous support and generates steady income for service providers, ensuring long-term sustainability.

Beyond Individual Farms: Sector-Wide Benefits

Genomic selection benefits more than just individual farms. Healthier and more productive herds lead to higher milk yield and strengthen the dairy sector as a whole, contributing to food security. This progress can position India as a competitive player in global dairy markets with higher-quality exports. Achieving this vision will require continued investment, research and farmer education.

Financial Sustainability and Long-Term Benefits

While the initial costs of genomic selection are significant, the return on investment (ROI) is compelling. As productivity increases—whether through higher milk yields, healthier animals or better reproductive performance—farmers will see tangible financial benefits. International studies have shown that genomic selection can improve herd productivity by 15% - 20%, which translates directly into higher income for farmers over time.

Furthermore, improving the genetic quality of livestock will also make Indian dairy farming more competitive on the global stage. With better breeds, India can meet its growing domestic demand for dairy and also explore opportunities for exporting high-quality milk products. This economic upliftment will benefit not just individual farmers but the rural economy as a whole.

A Collaborative Path Forward

Advancing genomic selection is a collective effort that involves researchers, the scientific community, policy makers, farmers and sponsors. While challenges remain, the potential benefits make this journey worthwhile. We invite all stakeholders to come together to make genomic selection a practical and empowering tool for farmers, driving growth and strengthening India's dairy sector for generations to come.

Shrinivas Kulkarni is Group Vice President, Finance at BAIF.

Voice of Programme Participant

Tejashree Shirsath

Latabai Dhyaneswar Rothe, from Yeola in Nasik, Maharashtra, is a 42-year old widow who had to assume the responsibility of taking care of her young daughter and elderly mother-in-law. In the absence of any assured source of income, Lata had to manage the household on the 2.5 acres of agricultural land owned by the family. As the income from agriculture was inadequate, in 2017, Lata joined the Enhanced Genetics Project (EGP) of BAIF. Under this project, her cows were bred with semen of very superior genetic merit. Thus, the male calves were procured by BAIF at a high premium to rear as breeding bulls. She owned two cows and two calves and each cow produced an average of 25 litres of milk per day. She was able to sell 45 to 48 litres of milk a day and earn a monthly income of Rs. 20,000–25000. With the project support, she ventured into fodder production, producing homemade silage for her herd. She also invested in building a house, cattle shed and a water storage tank. She also sells cow dung at Rs. 5000/trolley per month as an additional source of income. With proper feeding and vaccination, she is able to maintain a herd of healthy animals. She attributes the transformation in her economic status to genetic upgradation and is grateful to BAIF for giving a boost to the economy of farmers.

News Capsule

Technical Advisory Group Meeting of Enhanced Genetics Project

The 4th Technical Advisory Group (TAG IV) meeting under Phase II of the Enhanced Genetics Project sponsored by the Bill & Melinda Gates Foundation, was held between January 30 and February 2, 2024. TAG members - Dr. Alfred de Vries, Dr. Djikeng Appolinaire, Dr. Raphael Mrode, Dr. B.P. Mishra, Dr. Vincent Ducrocq, Dr. Mekki Boussaha, Dr. Mohammad Al Kalaldeh, Dr. Roy Costilla, Dr. Ben Hayes, Ms. Christie Warburto and Dr. John Gibson participated in this meeting. The discussions focussed on developing a roadmap for genomic selection and application at the national level in coordination with National Dairy Development Board. Dr. Bharat Kakade, President, BAIF, provided valuable inputs for the future direction of the programme. Dr. Ashok Pande, Senior Advisor, BAIF, Dr. Jayant Khadse, Vice President, BAIF and the BAIF Livestock Genomics team of scientists also participated in this meeting.

Collaborative Research on Animal Biotechnology

Dr. Bharat Kakade, President and Managing Trustee, BAIF and Dr. G. Taru Sharma, Director, National Institute of Animal Biotechnology (NIAB) signed a MoU on September 19, 2024 for collaborative research in livestock genomics and reproductive biotechnology. This collaborative effort is in huge sync with the BioE3 Policy recently announced by the Union Cabinet.

BAIF and NAIB are already engaged in a collaborative project on Livestock chip development in association with the National Dairy Development Board (NDDB).

BAIF and NIAB will design and implement programmes aimed at innovative solutions, scientific progress and positive societal impact and their dissemination among communities, policy makers and industry through lectures, workshops and contact programmes organised at the national and international levels.

Registration with R.N.I., Registration No.: 39839/82

Post

National Dairy Development Board
@NDDB_Coop

आज एनडीडीबी के लिए गर्व का दिन है की माननीय प्रधानमंत्री श्री @narendramodi जी ने 'विकसित और आत्मनिर्भर भारत' की दिशा में एक महत्वपूर्ण कदम उठाते हुए, अपने कर कमलों से वाशिम, महाराष्ट्र में किसान सम्मेलन के दौरान एनडीडीबी एवं @Dept_of_AHD द्वारा की गई दो महत्वपूर्ण तकनीकी पहलों को राष्ट्र को समर्पित किया गया।

एनडीडीबी द्वारा स्वदेशी रूप से विकसित सीमेन सेक्स् सॉर्टिंग तकनीक, जो @iiscbangalore और @iitmadras के सहयोग से विकसित की गई है, के उपयोग से, 85-90% मादा बछिया का जन्म सुनिश्चित करेगी। इस स्वदेशी तकनीक से किसानों को सेक्स्ड सीमेन क़रीब ₹ 250 में उपलब्ध होगा अतः ज्यादा किसान इसका लाभ ले पाएंगे जिससे दुग्ध उत्पादन मे वृद्धि होगी।

एनडीडीबी द्वारा एनबीएजीआर (@IcarNbagr), एनआईएबी (@HydNIAB), और बीएआईएफ (BAIF) के सहयोग से विकसित जीनोमिक चिप 'गौचिप' और 'महिषचिप', देश के जीनोमिक चयन कार्यक्रम के लिए एक महत्वपूर्ण उपकरण साबित होंगे। जीनोमिक चयन से किसानों को कम उम्र में ही उच्च गुणवत्ता वाले पशुओं की पहचान करने में मदद मिलेगी।

Translate post

The 'Unified Genomic Chip' – 'Gau' chip for cattle and 'Mahish' chip for buffaloes will help farmers to identify young, superior quality bulls at an early age for selection and thereby boost livestock productivity.