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2.2 The benefits of sex-sorted semen for smallholder dairy farmers in India

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Background

India continues to be the largest milk producer in the world, producing 210 million tonnes from 2020–21. Several measures have been initiated by the government to increase the productivity of the individual dairy animals, which can be witnessed by annual growth of 5.8 percent in milk production (Department of Animal Husbandry and Dairying, 2022). One technology, artificial insemination (AI), has been instrumental in disseminating the best possible genetic resources in the form of semen, leading to enhanced milk production among the smallholder dairy farmers of India.

Due to growing mechanization in the agriculture sector, the demand for bulls as draught animals has been reduced drastically. Apart from this, male calves are lost from the system either through early calf mortality or are released into the village commons where they roam unattended. These released bulls become a nuisance for planned breeding interventions. Additionally, anti-slaughter laws in cattle hinder further progress in the dairy industry. The conventional AI technology alone will not be able to bring the desired improvement in building the dairy heifer stock. Therefore, a technology like sex-sorted semen (SSS), which can boost the production of heifers, is highly desirable for building a profitable smallholder dairy sector.

BAIF Development Research Foundation (https://baif.org.in/), located at Uruli Kanchan village near Pune, India, has been involved with dairy development programmes through door-to-door cattle and buffalo AI and other relevant services to about 2.65 million families of smallholder farmers in over 86 000 villages in 12 states by their 4 247 cattle development centres per annum. The present case study addresses the efficiency of use of SSS in the herds of Indian smallholder farmers.

Project approach

The performance of SSS has been successfully demonstrated in other countries. However, in India, at the time of implementation of the SSS pilot project in 2016, no such studies had been carried out to evaluate the performance of SSS under the smallholder dairy system. Therefore, no information was available to benchmark SSS performance in India.

The piloting of SSS was planned using the financial assistance of the Bill and Melinda Gates Foundation (BMGF) with a set objective to understand the performance of the technique in terms

Table 1. Cost of SSS inseminations to the farmers

Cost	No. of inseminations
Up to Rs. 100	85 598
Rs. 100 to 250	68 329
Rs. 250 to 600	48 402
Rs. 600 to 1 200	29 479
Rs. 1 250	23 585
Total	255 393

of conception rate and female birth ratio under diverse production systems. The piloting was also expected to provide guidance in framing appropriate policy decisions for the use of SSS.

The programme of SSS was carried out between November 2016 to December 2018 by importing SSS of pure Holstein Friesian and Jersey breeds. The initiative was implemented in nine Indian states, namely Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, Odisha, Maharashtra, Andhra Pradesh, Telangana and Karnataka in over 700 cattle development centres. Training was given to all AI technicians for the usage, storage of semen and insemination. Simultaneously, the individual AI information, and its subsequent follow-up to calving, was stored using an online mobile application.

The unsubsidized cost of SSS was Rs. 1 250 (about 16 dollars) to the farmer. However, a few state governments and other stakeholders provided subsidies to introduce this technology at an affordable price. Sex-sorted semen was provided at the actual cost to farmers where the subsidies were not available (23 585 inseminations, just 9.2 percent of the total). The subsidized SSS prices resulted in comparatively higher inseminations as farmers had to pay less (231 808 inseminations, 90.8 percent of the total). Table 1 shows the prices paid by the farmers.

The SSS technology has a limitation of producing on average 90 percent female calves and 10 percent male calves. Inseminations were only carried out after obtaining consent from the farmer about the probability of this sex ratio. The consent is obtained from farmers to inform them about the possibility of producing 10 percent male calves. This helped to avoid future conflicts that might occur post-calving.

Technology of semen sexing

The SSS technology, developed and pioneered by the company Sexing Technologies based in the United States of America, was used in the semen sexing process. The technology is able to separate sperm bearing X or Y chromosomes on the basis of differences in their DNA content using a laser-based technology called flow cytometry. The semen is processed for sorting using the method described by González-Marín *et al*. (2018). The SSS production laboratory at the BAIF frozen semen station in Uruli Kanchan, Pune, is one of the best in India in terms of infrastructure, diverse bovine breeds availability and quality of SSS.

Every single batch of SSS produced was subjected to a quality standard protocol. Some of the standards included gender purity of more than 90 percent, the removal of dead sperm and ensuring a final concentration of at least 2.1 million sperms/straw.

Project results and its perceived impacts

A project of SSS use in farmers' herds was carried out in two phases. First was the piloting of imported semen of Holstein Friesian and Jersey pure breeds from Sexing Technologies. In this phase, 40 000 inseminations were carried out from November 2016 to December 2018 with a conception rate of 45.9 percent confirmed by transrectal palpation of pregnancy diagnosis 60–90 days after insemination on follow-up basis. Out of 13 113 calves produced, 11 814 (90.1 percent) female calves were produced. Contrary to the global recommendation of the use of SSS on heifers for better results (Borchersen and Peacock, 2009; DeJarnette, Nebel and Marshall, 2009; Frijters *et al.*, 2009 and De Vries, 2010), the success rates in multiparous animals were equally good.

The success rate in terms of conception and sex ratio under the smallholder dairy system led to BAIF initiating the second phase by setting up a SSS facility at the BAIF semen station to produce SSS of crossbreds, local cattle and buffalo breeds in November 2018. The conception rate of 43.3 percent with 90 percent female calves born out of 14 734 calvings was the outcome of 215 393 sorted semen produced at the BAIF facility.

Theoretical estimation of the economic benefits

Table 2 contains the results of an economic study comparing the use of SSS versus conventional non-sexed semen. In theory, this biotechnological intervention in the BAIF programme alone can result in the creation of an estimated asset worth 1 043 million rupees (about USD 13 million dollars) in the form of additional females produced and the potential to generate 2 085 million rupees (about USD 26 million dollars) worth of milk per year at the doorstep of smallholder dairy farmers from the third year onwards for the next six years or so, compared to the use of conventional semen.

In total, the estimated surplus worth produced by smallholder dairy farmers can be 3 128 million rupees (about 39 million dollars). However, these are not actual economic evaluations and may vary with the actual economic gain. Also, the study does not account for the additional costs of using SSS versus conventional semen. Similarly, actual economic analysis is not carried out of the impacts for the farmers of using SSS versus using conventional AI.

Table 2. Theoretical estimation of the economic value of heifers produced from conventional semen versus SSS

Parameters	Conventional semen	Sorted Semen
Total number of inseminations in 5 years	255 393	255 393
Conception rate (%) on actual basis	45.00%	43.90%
Estimated number of pregnancies	114 927	112 118
Female calf births	50%	90%
Number of female calves born	57 463	100 906
Female calf loss up to heifer stage	20%	20%
Mature heifers produced	45 971	80 725
Assumed market value of one heifer (rupees)	30 000	30 000
Total value of heifers produced (million rupees)	1 379	2 422
Surplus heifer value through use of SSS (million rupees)		1 043
Estimated average milk yield per lactation (kg)	2 000	2 000
Average milk price per litre (rupees)	30	30
Estimated value of milk produced from additional heifers produced by SSS (million rupees)		2 085
Estimated surplus net worth generated through SSS inseminations (million rupees)		3 128

Challenges encountered during the implementation process

Cost of SSS artificial insemination delivery

The major hurdle in the implementation process was the cost of single SSS insemination. In a developing country like India where conventional insemination costs range from Rs. 40 to 200 (0.5 to 2.5 dollars) the cost of SSS was almost six times higher, and therefore expensive for many smallholder farmers, despite its merit over conventional AI. As the technology is patented, it will be difficult to reduce the cost of production in the present scenario unless some new technology is developed with similar results under field conditions and at a lower cost. To solve this issue, BAIF approached different state governments, milk unions and companies to provide support to SSS services at a subsidized rate so that farmers would adopt this technology and could benefit from it. The financial assistance provided by different agencies helped to demonstrate the usefulness and performance of SSS to smallholder dairy farmers.

Birth of male calves

As per our results, 10 percent of male calf births were recorded. The farmers whose animals had male calves produced in their farm were nevertheless encouraged by the success stories of their neighbouring farmers. Because of this, 15 percent of these farmers opted for SSS for the next inseminations.

Mr Bhanu Mahato, a farmer from the Patratu village of Jharkhand State had 26 Holstein Friesian crossbred animals and had been using service from BAIF AI technicians since 2009. During an interaction with the farmer on his experiences with the use of SSS he replied, "I don't know whether the technology works or not but if I am able to get one less male calf, it will be a win-win situation for me, and the amount spent on SSS inseminations will be recovered." Nine of his animals were inseminated with SSS, out of which seven animals became pregnant. From these seven pregnancies, the farmer obtained seven female calves.

Figure 1. Interaction with an early adopter of SSS technology

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Disturbance in activities due to COVID-19 pandemic

The progress of SSS inseminations was halted by the emergence of the COVID-19 pandemic. The pandemic led to a complete or partial lockdown in the country, which reduced animal breeding activities. This reduced the number of inseminations and their subsequent follow-up compared to before the pandemic. Conditions got worse with the reduction in the price of milk, and farmers were forced to sell animals to meet urgent family needs. However, as the pandemic slowly subsided, breeding activities recovered and have now normalized.

Factors that contributed to the success of SSS implementation

Farmer awareness programmes

Awareness about the technology paved the way for its adoption by smallholder farmers. The farmer awareness involved mainly individual village-level farmer meetings, posters and local newspapers. To spread the benefits of SSS to a wider range of farmers, a mobile call tune (farmers get to hear this voice message when they call the AI technician to inseminate their cows) explaining the benefits of using SSS was prepared in local languages and was set on each AI technician's incoming calls so that farmers would get to know about the merits of the technology.

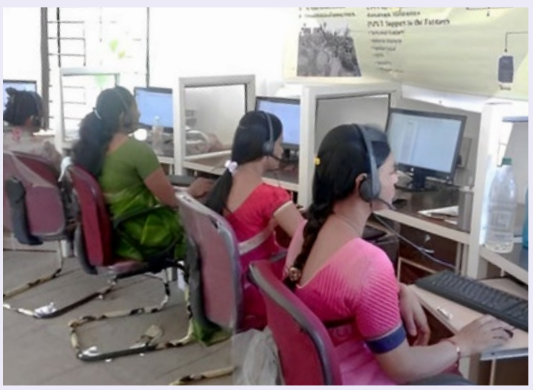
BAIF launched another initiative through their own call centres known as "samvadini", operated by female staff, where the operator calls the farmers to create awareness about the use of SSS, resolving any technical questions, doubts or misconceptions regarding the SSS or its use in Indian cattle and buffalo populations through expert opinion. Social media platforms like WhatsApp groups for farmers were also created and any news related to awareness programmes and success stories was distributed regularly.

Figure 2. Farmer awareness activities

(A) Farmer awareness programme: AI technicians' rally

(B) Project official disseminating the benefits of SSS

(C) Village-level farmer meeting



(D) Samvadini: Outbound call centre to create awareness about the use of SSS

Figure 3. A successful farmer with crossbred progeny produced from SSS inseminations

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Use of SSS for high genetic merit bulls

The technology was intended to produce more heifers with high genetic potential. For this purpose, imported high genetic merit Holstein and Jersey bulls for production and reproduction characteristics were selected in phase I of the project on the basis of their phenotypic records and genomic estimated breeding values which indicate the genetic value of the animals for the respective production and reproduction characteristics. Later on, high genetic merit bulls of crossbreds, local cattle and buffalo breeds from the BAIF bull stud farm were selected on the basis of the dam's 305-days lactation yield for SSS production in phase II, resulting in males that are much more adapted to local production systems.

Experienced AI technicians

At the time of implementation, the technology was new for the farmers and its adoption was dependent on its success in smallholder dairy farms. To win the confidence of the farmers, implementation of the project was initiated through experienced AI technicians who had been working with the farmers experienced in conventional inseminations and who had achieved good conception rates. The AI technicians performed inseminations only when the cow/buffalo had shown proper heat symptoms and ensured the per rectum examination of the animals. This factor proved to be very successful as farmers who were hesitant to use SSS earlier slowly adopted the technology.

Figure 4. Verification of SSS doses by the programme officials at the farm

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Visible results in the ratio of female to male calves and conception rate in herds

A major factor for the success of SSS implementation in farmers' herds is the 90 percent birth of high genetic merit female calves compared with the outcome of conventional semen. This led to word-of-mouth publicity among the farmer community and resulted in increased demand for SSS. This, coupled with the subsidy provided by milk cooperatives, corporates and state departments, led to more adoption. The birth of more females also resulted in fewer calving problems, thereby improving the future conception rate. Out of 27 831 calvings, only 70 (0.25 percent) were difficult. This indicated a lower incidence of dystocia in animals inseminated with SSS in the programme. In addition, problems related to male calf disposal declined, resulting in decreased economic loss. The surplus female calves born also served as an income source, as they could be sold as surplus heifers.

Access to sorted semen

The infrastructure for the SSS delivery system was built to ensure an uninterrupted supply of good quality semen with doorstep delivery to the farmers' herds. The SSS was dispatched to AI technicians once or twice a month with a regular supply of liquid nitrogen.

Real-time tracking of the SSS straws

A mobile based software solution was developed to track semen supply, semen repositories at individual AI technicians, delivery and record keeping of individual inseminations and pregnancy diagnosis up until the birth of the newborn calf. Straws used for insemination were kept by the farmer with a signed consent copy.

Trust of farmers in BAIF

BAIF has been working with farmers for more than 50 years to improve their livelihoods through livestock and other related activities. The uninterrupted quality service and support for the dairy development programmes offered by BAIF is instrumental in building trust between farmers and BAIF, which helped BAIF introduce SSS under the Indian smallholder system despite the higher price.

Subsidies to make SSS affordable to smallholder farmers

With the high financial burden of individual SSS inseminations for farmers, it was necessary to try to reduce the cost. The main aim of the programme is to encourage farmers to adopt the newly proven technology that could help them to increase their herd size, create replacements for their older cows, prevent the birth of unwanted male calves (due to anti-slaughter laws in the country) and subsequently increase milk production, thereby boosting the income of smallholder dairy farmers. The government wants farmers to adopt the SSS technology because many farmers release their male animals, which then become a nuisance in terms of damage and loss of agricultural crops from uncontrolled grazing, disturbances to vehicles, difficult-to-control contagious diseases and, crucially, indiscriminate breeding leading to genetic erosion.

The SSS initiative was supported by subsidies from different state governments and other agencies working closely with the dairy and livestock sectors. The cost of inseminations to farmers, most of which were subsidized, is presented in Table 1. Subsidies to reduce the cost of SSS inseminations were provided by state governments like Uttar Pradesh, Jharkhand, Odisha, government agencies like the National Bank for Agriculture and Rural Development (NABARD) and dairy cooperatives like Godavari Dairy Private Limited. Apart from governments, subsidies were also provided by different companies under their corporate social responsibility activities to promote the use of SSS among smallholder farmers. All of these are once-off subsidies and hence not available every year.

Lessons learned from the implementation of SSS in smallholder farms

Selection of animals for SSS AI

Considering limitations such as the cost of SSS delivery to the farmer and low sperm concentration (approximately 2 million sperm per dose), it was important to select animals with a normal estrous cycle, have proper heat detection, measure body weight as an indirect way of confirming physiological development and to use cows with no history of repeat breeding, preferably heifers. The selection of animals with these criteria increased the likelihood of animals becoming pregnant, and farmers incurred fewer economic losses.

Successful use of SSS in multiparous animals

According to the literature, it is usually advised to use SSS in heifers only (Borchersen and Peacock, 2009; DeJarnette, Nebel and Marshall, 2009; Frijters *et al.*, 2009). In the pilot study, SSS was used not only in heifers but also in multiparous animals, with good results both in terms of conception rate and the birth of female calves.

Farmer consent

It is highly recommended to obtain consent from the farmers about the possibility of the offspring being 10 percent male before performing insemination with SSS.

Conclusion

BAIF will continue to explore the possibility of providing smallholder dairy farmers with access to valuable and high genetic merit bulls' SSS at an affordable cost, to improve genetic progress by cross-subsidizing SSS delivery cost through milk unions, state governments and private companies under corporate social responsibilities. Specific efforts can also be undertaken for local breeds that are on the verge of becoming extinct. Through a special breed development programme, with the use of SSS for faster multiplication of the female population, the respective breed can increase its population size within a stipulated time. In addition to this, the use of SSS coupled with genomic selection in cattle and buffaloes will help to increase the rate of genetic gain of the endangered breeds, thus making them more economically competitive and more sustainable in the long term.

The scope will also expand to produce Y-sorted semen in the future for some of the draught purpose cattle breeds like Khillar, Hallikar and others. Apart from these initiatives, BAIF is looking forward to producing high genetic merit embryos using SSS to multiply the genetic pool as well.

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