REVIEW ARTICLE Bhartiya Krishi Anusandhan Patrika, Volume 40 Issue 2: 129-137 (June 2025)

Exploring the Genetic Dimensions of Sex-sorted Semen: A Review

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10.18805/BKAP826

ABSTRACT

Sexed semen is one of the strategies that dairy producers nowadays need to use in order to have an upper hand in the market. Several techniques for separating the X and Y chromosomes have also been developed, based on variations in swimming patterns, differences in bulk and motility, the presence of surface charges and immunological variances. In order to enable farmers to receive the greatest benefits from dairy farming, a number of government breed development schemes currently use sexed semen technology. A few available elite cows might be used to make superior bulls by adding sexed male sperm. Sexed semen technology ensures that each bull has the required number of offspring under the progeny testing scheme, improving the accuracy of bull testing. By selecting replacement dams that are genetically superior, selection intensity is raised, accelerating the pace of genetic gain in dairy herds. A decline in the number of Y chromosomes in population of the subject breed could eventually lead to Y chromosome degeneration and extinction, with major and unanticipated implications. Over exploitation of sexed semen for inseminating elite dairy animals will eventually dilute the superior germplasm and also will lead to inbreeding depression in a dairy herd over a period of time. Therefore, careful consideration must be given to potential challenges such as reduced conception rates, genetic bottlenecks and maintaining genetic diversity. When integrated strategically, sexed semen serves as a powerful tool for advancing genetic improvement and sustainability in animal production systems.

Key words: Genetic gain, Replacement, Selection intensity, Sexed semen, Y chromosome.

In contemporary dairy farming, female animals are valued more than male animals and farmers and dairy producers see male animals as a burden. Young calves are fed less than their older counterparts and they may either slowly starve to death or be abandoned on the streets nowadays, which is dangerous for the stray animals in terms of probable accidental happenings *etc.* Therefore, sex-sorted semen (SSS) is a cutting-edge method of breeding cattle. Historical progression of sperm sexing over hundreds of years is depicted in Table 1.

Sexed semen may be used more effectively to boost dairy and beef production efficiency, farm profitability and environmental sustainability of cow agriculture (Holden and Butler, 2018). A female calf is more in demand in the dairy industry than a male calf in the meat industry due to their dependency on milk and milk derivatives. Several attempts have been made over the years to create an effective sperm sorting process, each employing a different set of sperm cell properties (Prasad *et al.,* 2010) as shown in Table 2. Several techniques for separating the X and Y chromosomes have also been developed, based on variations in swimming patterns, differences in bulk and motility, the presence of surface charges and immunological variances (Joshi *et al.,* 2021). Currently, the only successful method for creating distinct populations of X and Y sperm in mammals is to employ high-speed flow cytometry to differentiate DNA. It was developed there by researchers from Beltsville, Maryland, Livermore, California and the United States Department of Agriculture (USDA) and it was given a patent as the “Beltsville Sperm Sexing Technology. This technique, which is applicable to almost all animals, can result in populations of X or Y sperm that are purer than 90%, as well as offspring whose phenotypic sex is congruent with the initial purity of the sorted sperm population. Its usage varies greatly between species primarily due to biological variations in the location of semen deposition, duration of the cycle, desire for sperm quantities, sortability and freeability of spermatozoa, as well as economic demands and management requirements (Rath and Johnson, 2008). In cows, pigs, rabbits and sheep, the DNA contained in X- and Y-sperm cells could be accurately differentiated by flow cytometry (Garner *et al.,* 1983) but the flow cytometry technique somehow affects the survival of sperm cells. As a possible high-speed sorting method, LumiSort, a laser-based device based on

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How to cite this article: Jaglan, K., Dhaka, S.S., Dahiya, S.P., Ratwan, P., Patil, C.S., Ghanghas, A. and Sheoran, N.K. (2025). Exploring the Genetic Dimensions of Sex-sorted Semen: A Review. Bhartiya Krishi Anusandhan Patrika. 40(2): 129-137. doi: 10.18805/BKAP826.

Submitted: 18-12-2024 **Accepted:** 23-04-2025 **Online:** 23-05-2025

variations in DNA content that specifically eliminates undesirable spermatozoa sex, has recently been created (Lumisort-Microbix Biosystems, 2019). Nevertheless, spermatozoa separation using protein-based methods has not yet been developed for commercial use (Naidu *et al.,* 2025).

Not with standing the benefits of using sex-sorted semen, its share of the artificial insemination (AI) industry is still less *i.e.* 5% (although expanding quickly) owing to high costs associated (Seidel, 2014). Therefore, new separation methods that offer reduced costs and increased accuracy are required (Bhat and Sharma, 2020). Bovine spermatozoa are more suited for high-speed sorting than those of other species because of their high sorting index, which is based on the head profile area (μm^2) and X-Y sperm DNA differential (%) (Garner, 2006). The majority of sex-sorted semen is used in dairy herds and formerly, in dairy herds, it was only used on heifers due to worries about decreasing cow conception rates (DeJarnette *et al.,* 2011; Healy *et al.,* 2013). But it should be highlighted that using sexed semen is unlikely to be successful in herds with low fertility, any decrease in fertility will lower the financial benefits (Holden and Butler, 2018). One of the decisive aspects to enhance genetic progress and farmer profitability in either beef or dairy cattle may be the choice of desired sex. However, using sex sorted semen continuously on female population will ultimately result in diminishing of variance due to decrease in effective population size for implementing a breeding programme in a population of dairy animals. In order to achieve more efficiency, optimal sexing technology utilisation also necessitates outstanding and cautious animal management *viz.* nutrition, disease control, oestrus detection, handling semen and insemination technique (Kumar *et al.,* 2016).

This review summarises various methods developed so far for sex sorting, benefits and constraints of using sexed semen technology, ongoing projects for breed improvement using SSS, status of sexed semen technology in India as well as procurement of sexed semen along with available breeds (Table 3) and also focuses on all such genetic aspects which should be given a thought while implementing breeding strategies using sexed

Table 1: Historical progression of sperm sexing.

Hypothesis	References
Spermatozoa visualization using an improved microscope	Leeuwenhoek, 1677
Sex of offspring determined by male	Guyer, 1910
Differential density of X and Y sperm in rabbit	Lush, 1925
Spermatozoa DNA content (flow cytometry)	Gledhill *et al.,* 1976
X chromosome has more DNA than Y chromosome	Moruzzi, 1979
X and Y spermatozoa in livestock	Garner *et al.* (1983)
Modification of sex sorter	Johnson and Pinkel (1986)
Sorting of spermatozoa head by micrometry	Johnson *et al.* (1987)
First use of sex sorted semen in IVF	Cran *et al.* (1993)
Low dose insemination using sex sorted semen	Seidel *et al.* (1997)
Successful freezing of sex-sorted semen	Schenk *et al.* (1999)
Modified swim up technique using PCR	Awan *et al.* (2017)

Table 2: Semen sorting methods based on differences between X and Y Chromosome (Source: Prasad *et al.,* 2010).

Objectives	X chromosome	Y chromosome	Method
DNA content	More in X sperms (3.8%)	Less in Y sperms	Flow cytometry
Size	larger	smaller	Gradient centrifugation
Motility	slower	faster	Swim up
Surface charge	Negative	Positive	Free flow electrophoresis
Presence of cell surface HY antigen	Absent	Present	Immunological method

Table 3: Procurement of sexed semen along with available breeds.

Name of organization	Breeds
Deep frozen semen production centre (DFSPC) (Uttarakhand)	Cattle- HF, Jersey, Sahiwal, Red Sindhi,
• The first centre producing sex sorted semen (under Rashtriya Gokul Mission)	Hariana and Gir
• Became operational since March 2019	Buffalo- Murrah
BAIF (Bhartiya agro industries foundation) Urulikanchan, near Pune Maharashtra (Nov, 2018)	Cattle- Sahiwal, Gir, Tharparkar,
• Established in collaboration with sexing	Red Sindhi
• Technologies, Texas, USA	Buffalo- Murrah and Jaffarabadi
▪ BG Chitale Dairy at Brahmanand Nagar, Sangli district, Maharashtra	Cattle- HF, Jersey, Sahiwal, Gir
▪ Mehsana District Cooperative Milk Producers' Union (Gujarat)	and HF × Sahiwal, HF × Gir
▪ Uttar Pradesh Livestock Development Board, Babugarh, Hapur district (UP)	Buffalo- (Mehsana and Murrah)

semen technology such as long-term implications of sexed semen on demographic patterns, the degradation of Y chromosomes and the impact of artificial selection *via* SSS on holandric genes that have not yet been reported.

Methods of sorting sex of semen

Conventional methods

Several techniques for separating X- and Y-chromosomes have been described, based on differences in bulk and motility, swimming styles, surface charges, volumetric variances, centrifugal counter-current distribution and immunologically significant features.

Flow cytometry

One of the most effective sorting methods that is now commercially accessible is flow cytometry-based sorting by separating sperm before fertilisation based on their DNA content, with 85-95% accuracy in mammals (Seidel *et al.,* 1999). The first offspring whose sex was known before birth, using this technique, was born in 1988. These sperm separations are carried out with the use of a flow cytometer/ cell sorter that can distinguish between sperm carrying X and Y chromosomes by measuring the DNA content of each individual sperm as it passes through the apparatus using DNA-specific fluorochrome Hoechst 33342. X and Y-sperm cell differs in weight from 3.73% to 4.98% depending on the breed of cattle. *Bos taurus* cattle had an X and Y chromosome weight difference of 4.98%, while *Bos indicus* cattle had a weight difference of 3.73% (Garner and Seidel, 2003). Variations in the amount of DNA between X and Y carrying spermatozoa in several species has been shown in Table 4. According to Lu *et al.* (2007), the differences in DNA content between Murrah and Nili Ravi buffalo were 3.59% and 3.55%, respectively. As a result, optimum sorting accuracy and rate would be more challenging for buffalo sperm than for bovine sperm, whose X- and Y-sperm have somewhat higher difference in DNA contents. This technique for separating bovine sperm has been patented and made commercially available in United States, Europe and other countries. Nevertheless, these sorting techniques put sperm cells under stress, which lowers their *via*bility, fertility and conception rates compared to unsorted sperms, making it a less desirable strategy. This necessitates the creation of a fresh strategy with relatively greater conception rates that won't compromise sample quality (Joshi *et al.,* 2021).

Table 4: Variations in the amount of DNA between X and Y carrying spermatozoa in several species.

Species	Differences (%)	References
Cattle	3.7-4.24	Garner *et al.,* 1983; Johnson and Welch, 1999; Johnson, 2000; Garner, 2001, 2006
Buffalo	3.6	Johnson, 2000; Lu *et al.,* 2006
Sheep	4.2	Johnson, 1995; Johnson, 2000
Goat	4.4	Parilla *et al.,* 2004
Horse	3.7	Johnson, 2000
Swine	3.6	
Human	2.8	
Rabbit	3.0	
Camel	3.3	
Bison	3.6	
Yak	3.6	

Percoll density gradient

In this method, semen is layered atop of a percoll column and spermatozoa are allowed to flow through the column. The discrepancies between the sedimentation densities of spermatozoa bearing X and Y serve as the foundation for this approach. X-bearing sperm settles at the bottom of the column as have higher sedimentation density while Y-bearing spermatozoa stay at the top. Colloidal silica particles covered in polyvinylpyrrolidone make up percoll. When a percoll column is configured in a discontinuous gradient, spermatozoa stacked atop of the column are allowed to naturally enter the column and the depth of this penetration depends on both mass and motility of spermatozoa. As an alternative, centrifugation can be used to reduce the impact of motility and increase the mass difference (Prasad *et al.,* 2010). This method's accuracy ranges from 86% to 94% (Iizuka *et al.,* 1987). Sperm that are *via*ble are separated into a lower layer of high-density solution and non-viable sperm are separated into an upper layer of lower density solution (Kaneko *et al.,* 1983).

Free flow electrophoresis

This method is based on changes in electric charge on sperm surface carrying X and Y chromosomes. The X sperm surface is negatively charged whereas the sperm from a Y is positively charged. Under the presence of an electric field, X and Y carrying sperms are sorted based on the variations in their surface charges (Kaneko *et al.,* 1983; Mohri *et al.,* 1986). The mobility of sperm is greatly decreased after electrophoresis, which is a limiting factor in its current use.

Creation of antibodies against H Y-antigen

Sperm cell separation using antibodies is expected to be possible using sperm surface antigens or proteins that are specific to either X or Y sperm (Goldberg *et al.,* 1971; Quelhas *et al.,* 2021). Spermatozoa were sorted using affinity chromatography or magnetic beads using specific antibodies against the H-Y antigen, which is produced in spermatozoa that carry Y gene with a success rate claimed to be around 90 per cent (Hendriksen *et al.,* 1996; Blecher *et al.,* 1999; Hendriksen, 1999).

Novel approaches

Raman spectroscopy

The investigation of fixed amembranous human spermatozoa was the main application of Raman micro-spectroscopy.

Differences between the Raman spectra of spermatozoa chromatin in normal and aberrant spermatozoa nuclei were found to be connected to proteins and DNA (Naidu *et al.,* 2025). Raman spectroscopy, which identifies vibrations of chemical bonds in molecules *via* inelastic scattering of light, is the most alluring label-free technique (Dochow *et al.,* 2011). It serves as a kind of molecular "fingerprint" of the sample, offering chemical data such as molecular composition of cell, structure and physiological status of cell, allowing for the differentiation of distinct cell kinds and states (Ashok *et al.,* 2011). Also, it does not need a label or marker, for example, fluorescence, making it possible to analyse the materials *in situ* quickly and non-intrusively. Raman spectroscopy is a label-free, non-destructive method for analysing the biochemistry of a wide range of cells, organelles, bacteria, viruses and other microorganisms. Bovine X and Y sperm cells are selectively and sensitively distinguished using a method based on Raman spectroscopy. Also, this technique enables the study of different sex-related membrane protein components in X- or Y-bearing sperm.

Nanotechnology for sex sorting

The livestock industries are under tremendous pressure to boost productivity without sacrificing quality due to the growing population. This highlights the need for creation of a new, cutting-edge strategy to address difficulties related to growing market demand. The front-runner in this race has emerged as growing popularity of nanoparticle and microfluidics-based techniques. The following are three important parts of this technology: 1) Functionalized AuNPs passing through the sperm membranes. 2) Non-invasive triplex binding that couples a particular DNA probe having intact DNA double strand. 3) Identification of the sperm population's sex-specific signal pattern. Zeta potential is the name for the membrane charge that develops between a solid and liquid surface. According to Dominguez *et al.* (2018), the Y spermatozoa possess zeta potential of -16 mV while the X spermatozoa have -20 mV. This makes Y spermatozoa more likely to form complexes with magnetic nanoparticles than X chromosome. The Y chromosome complex with magnetic nanoparticle beads was attracted towards the inner wall of test tube, whereas sperm cells bearing X chromosome remained floating in the fluid and could be collected separately. Microfluidic dielectrophoretic-based chips have also been developed using this variation in membrane potential. Dominguez *et al.* (2018) demonstrated the use of magnetic nanoparticles in the separation of X sperm cells in donkeys. Using this method, they reported a 90% efficiency without compromising any sperm functioning.

Genetic advantages of using sex sorted semen

Genetic progress

More dams can be chosen using sexed semen technology, but the consequences on the rate of genetic change as a whole are anticipated to be modest. Secondly, males are subject to significantly stronger levels of selection than females. Even with the widespread usage of sexed semen, only around 0.1% of all male calves produced each year will be used as sires and at least 60% of females of breeding age must produce enough replacements. Estimates of genetic merit for sires are far more accurate than those for dams because unlike dams, who hardly ever have information from any daughters, information from numerous daughters will be available for proven sires. Moreover, dams frequently lack access to their pedigree's genetic information (De Vries *et al.,* 2008). When sex sorted semen is used on a large scale, a dairy population should expect a maximum 15% boost in genetic improvement (Van Vleck, 1981). In a dairy cattle breeding strategy that used genomic selection, Pedersen *et al.* (2012) found that the use of sex-sorted semen in both the nucleus and production populations resulted in a genetic gain of 6% in the total merit index. Boustan *et al.* (2014) predicted an uplift of 25 and 34-38%, respectively, after using sex-sorted semen for traditional and genomic evaluation through simulation study.

Production of elite breeding bulls and improved accuracy of progeny testing

There is a dearth of superior breeding bulls in our nation. The demand for bovine semen in India has reached nearly 150 million doses during the previous five years (Sharma *et al.,* 2024). As of 2022, 27.86 lakh doses of sex sorted semen have been produced at government semen stations assisted under the Rashtriya Gokul Mission and 31.12 lakh doses have been produced at milk federation, NGO and private semen stations (Ministry of Fisheries, Animal Husbandry and Dairying Year End Review, 2022). Few available elite cows might be used to make superior bulls by adding sexed male sperm. However, sex-sorted spermatozoa from superior dam can generate superior males, which will be a wonderful boost for semen stations, which are urgently needed to increase the productivity of frozen semen in the nation. Sexed semen technology ensures that each bull has the required number of offspring under the progeny testing scheme, improving the accuracy of bull testing. In order to produce the desired number of daughters (10 daughters per bull to be tested) in the shortest amount of time, the sexed female sperms could be employed in test mating, enhancing the genetic gain (Kumari *et al.,* 2021).

Increased genetic gain

It has been proposed that sexed semen could be used as a method to boost or speed up the rate of genetic gain in dairy herds (Kumaon and Kharche, 2014; Kumari *et al.,* 2021). Three elements in the genetic progress equation are changed by genomics and sex-specific sperm (Vishwanath and Moreno, 2018).

$$\Delta G = \frac{i \times r \times \sigma}{GI}$$

Where,

ΔG = Progress in genetic standard deviations per year.

i = Selection intensity.

r = Accuracy of selection.

σ = Genetic standard deviation in the population under selection.

GI = Generation interval.

Schaeffer (2006) asserts that the use of genomic selection alone can double the genetic advancement made each year across all channels of selection. The commercial dairy industry has most potential for sexed semen. In the past, commercial dairies either had very little or no selection on female side. This is because dairy farmers need to keep every single born female just to sustain herd size at replacement rates of 40%, accounting for calf losses and a 50/50 sex ratio. As a result, there hasn't been much evolutionary development along the dam-to-dam selection pathway. By skewing the sex ratio, sexed semen provides a mechanism to initially introduce selection in that route. Only the selection intensity (i) component exhibits the effect. Prior to the sexed semen option, (almost) 100% of the selected females were female, which produced very little genetic advancement. Therefore, utilising currently accessible technology combined with genetic selection and sexed semen can accelerate genetic advancement in the dam-to-dam route by a factor of 3 to 5 (Heuer *et al.,* 2017). However, genetic gain is only slightly increased by semen sexing if cows' estimated breeding values (Individual/Pedigree selection and Progeny testing methods used in India) have low accuracy, as it is usually the case without genomic information. Therefore, a synergistic use of genomic selection, use of sexed semen and optimization of replacement is required to obtain some additional genetic gain.

Genetic implications of using sex sorted semen

Conception rate

According to various studies, conception rates can range between around 60 and 90 per cent of traditional semen (DeJarnette *et al.,* 2010) but lower conception rates (30%) (Sharma *et al.,* 2024) have been reported when sexed semen used in conjunction with fixed-time AI (Thomas *et al.,* 2017). A study was conducted in Ireland to assess the fertility of SSS having 4×10^9 sperms per dose in lactating dairy cows where semen from HF (n = 8) and Jersey (n = 2) bulls was used (Maicas *et al.,* 2020).Generalized linear mixed model was used to examine effects on pregnancy per AI (P/AI) at first artificial insemination with sperm treatment (conventional vs. sex sorted) (CONV vs. SS), taking 10 bulls and treatment × bull interaction as the fixed effects and herd size of 142, as a random effect. Overall, P/AI was greater for cows whose insemination was done with CONV (59.9%) than for those inseminated with SS (45.5%) *i.e.* 76.0% relative to that of conventional semen. Targeting early-calving young cows with the highest reproductive potential when applying SS can boost the likelihood of a successful pregnancy establishment. Additionally, they came to the conclusion that adding a capacitation-like modification analysis to the post-sorting quality control could aid in identifying and eliminating impacted ejaculates and bulls prior to straw distribution. In a study done by Chebel *et al.* (2010), Holstein heifers were given their first artificial insemination (AI) with either sex-sorted semen or conventional semen to see how it affected their productivity and health during their first lactation. Pregnancy per AI after first AI: CS heifers > SX heifers (51.8 vs. 40.2%) which might be likely because of reduced sperm cells per inseminating dose and possible damages to sperm cells during sperm sorting. Conclusively, for the initial AI of heifers, herds that need to grow in size and those that sell female calves and heifers ought to use sex-sorted semen.

Population dynamics and sex-sorted semen

Effective population size, $N_e=1/4N_m +1/4N_f$ (Falconer and Mackay, 2009), Therefore, the likelihood of its survival increases when the N_m:N_f ratio de*via*tes from 1:1 and the population size N_e approaches N_c (Census Population). Further, Falconer and Macay (2009) state that if an arbitrarily large number of females but only one male were produced in each generation, the population's effective number would only be four. So by reducing the male population, we would ultimately be reducing N_e, albeit the Nc might be increasing, which would increase the population's vulnerability to danger. In reality, Wedekind (2002) claims that genetic issues are only tangentially related to the census size (Nc) because effective population size is so important. The genetically effective population size (Ne), which is the size of a perfect model population that loses genetic diversity at the same pace as the actual population, is a factor that they inadvertently rely on. He continues by stating that Ne is substantially smaller than Nc due to individual reproductive success variability, de*via*tions from the operational 1:1 sex ratio and other factors.

Inbreeding level

Without significant countermeasures, the major dairy breeds' average level of inbreeding will keep rising. In order to initially meet the high demand for dairy replacement heifers, sexed semen will be widely used. The purchase price of heifers is anticipated to drop as the supply of replacement heifers increases and meets the demand. The average cost of a cow in the herd will reduce due to the drop in heifer pricing (De Vries *et al.,* 2008). Effective population size (Ne) as defined by Tomar (2019) means that the number of individuals that would give rise to the same rate of inbreeding, if they bred in the manner of an idealized population, in which the rate of inbreeding is:

$$\Delta F = \frac{1}{2N_e}$$

N_e = Amount of inbreeding expected.

In an idealized population, the number of sires and dams should be such as:

$$\frac{1}{N_e} = \frac{1}{4s} + \frac{1}{4D}$$

Where,
S and D = Number of sires and dams respectively.

Therefore, continuous use of female sorted semen will consequently lead to fewer males in the population and that would eventually result in a decrease in the Ne, therefore, rate of inbreeding will increase. However, use of female sexed semen decreases the number of male calves born, but not the number of sires which is much lower, especially in artificial insemination. Therefore, this aspect can be taken care of even while using sexed semen and needs to be practically assessed over years.

Selection proportion of sire of dams selection pathway in a nucleus programme

Joezy-Shekalgorabi studied effect of utilizing sex sorted semen on selection through sire-dam pathway (pSD) through a deterministic simulation, in three different strategies including

1. Continuous use of sex sorted semen in heifers (CS).
2. The use of sex sorted semen for the first two (S2).
3. The first (S1) inseminations followed by conventional semen.

Their research indicates that the sire of dams (SD) pathway is negatively impacted by the use of sex-sorted semen due to an increase in the selection proportion. The decrease in the quantity of sperm *via*ls that might be acquired from each verified sire is the cause of the SD pathway's diminishing selection intensity. In light of the poor impact of sexed semen on genetic improvement in dam pathways, they concluded that the combined effect of using sex sorted semen on the sire and dam route must be taken into account in order to determine the true effect of sexed semen on genetic improvement in a nucleus breeding scheme.

Altered genetic architecture of the population due to degeneration of Y chromosome

According to Muller (1914), the sex chromosomes originate from a pair of autosomes. Ex chromosomes of mammals are very dimorphic. The little heterochromatic Y and large gene-rich X are almost entirely distinct from one another, yet they couple across a tiny homologous region at one (the pseudoautosomal region). About thousand genes with a range of general and specialised functions are present in the 165 Mb human X gene (Ross *et al.,* 2005). With the XY system of sex determination, selection against Y chromosomes that are already deteriorating in cattle, we should be prepared for even faster deterioration, if not complete elimination, of the Y-Chromosome (Kumari *et al.,* 2021). According to Graves *et al.* (2006), the computation of the rate of gene loss from Y indicates that eventually Y will lack in genes completely and cease to exist.

Genetic composition, gene frequency of the trait/s concerned *via* artificial selection

According to Falconer and Macay (2009), for selection against a recessive phenotype in the progeny generation is obtained as under:

$$q_1 = \frac{q - sq^2}{1 - sq^2}$$

Where,
q_1 = Gene frequency of the recessive allele.
q = Equilibrium gene frequency of a mutant allele in a population.
s = Intensity of selection.

For s = 1 (intensity of selection against the genotype=1) and for all other forces *i.e.* mutation and migration being assumed to be constant, Number of generations (t) needed to change q_t to q_0 can be obtained from the equation:

$$q_t = \frac{q_0}{1 + tq_0}$$

For, $q_t = (1/n)\ q_0$ *i.e.* for the gene frequency of the genotype selected against to be reduced to $1/n^{th}$ time the original, $t = (n-1)/q_0$.

The reduction in gene frequency in the equation above can be used to demonstrate the effect of artificial selection. This formula and illustration both illustrate how SSS affects the frequency of recessive genes found on Y chromosomes (Kumari *et al.,* 2021). However, Y-specific recessive defects are likely to be very rare.

CONCLUSION

The usage of sexed semen should be restricted to heifers and reproductively healthy cows, preferably upto first service, in light of the decreased conception rates compared to those of conventional semen. Mixed usage of conventional and sexed semen is preferred since second insemination reduces the fertility of heifers. Combining this technology with modern biotechnological techniques, such as multiple ovulations, embryo transfer technology, *in vitro* fertilisation, gamete intrafallopian transfer and sperm intrafallopian transfer, can also help to solve the problem of lower fertility that is associated with it. The sex-sorted semen should not be employed in animals with high genetic merit, which is most vital to be kept in mind in the Indian context. By doing this, we can protect and reduce the dilution of superior germplasm, allowing us to obtain high genetic merit males who can later be used as tested sires. Developing homegrown technology or improving current technology is required to lower the high cost of sexed semen. To reduce inbreeding, care should be taken to avoid fertilising all of the embryos with sex-sorted semen from the same bull. Additionally, regulating techniques should be carefully developed and put into practise to prevent inbreeding and to increase the success rate of employing sexed semen.

ACKNOWLEDGEMENT

The present study was supported by Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India.

Disclaimers

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Informed consent

NA

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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