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Open Nucleus Breeding System to Improve Livestock Population: A Review

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ABSTRACT

Genetic improvement in productivity per animal in the shortest possible time is the main aim of animal breeder. Though conventional selection and mating schemes have given significant contribution in genetic improvement of livestock in developed world, but their impact in developing countries like India have been on lower side. This is because of too complex breeding programs in terms of logistics, technology and other resources which is leading to wrong breeding objectives, negligence the potentials of various indigenous breeds of livestock. Nucleus herd breeding schemes are beneficial in many developing countries where the selection of breeding stock is concentrated in a few herds from which the selected animals are spread to other herds. Hence a breeder can achieve greater rate of improvement (up to 15- 25%) because of high selection intensity. The annual genetic progress in MOET – ONBS was 4-6 % higher as compared to classical progeny testing schemes and this response was reduced to 1- 2% when the nucleus was closed. It allows more rapid improvement with limited resources & data recording, which is practically most suitable for developing countries. ONBS (in combination with MOET) allows higher selection intensity in females, increases the number of viable offspring that can be obtained from a single elite female.

Key words: *Open nucleus breeding schemes (ONBS), Multiple ovulation embryo transfer (MOET), Adult MOET, juvenile MOET, Hybrid or mixed MOET.*

INTRODUCTION

The challenge to improve livestock population in developing countries lies in efficient exploitation of genetic diversity among and within breeds of different species. The most productive and adapted animals for each environment must be identified for breeding purposes. Only then will it be viable to improve the existing livestock population and subsequently increase food production efficiently. Many breeding programs for different species in temperate climates have shown the opportunities to increase the output per animal after a few decades of selection.

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The challenge is, however, to design sustainable breeding schemes for indigenous breeds under inherent tropical conditions where resources are limited, feed availability and quality varies greatly depending on the type, geographical location and season, and the demand of animals that are better able to adapt to the ever changing environment[20].

Genetic improvement in productivity per animal in the shortest possible time is the main aim of animal breeder, conventional selection and mating schemes have given significant contribution in genetic improvement of livestock in developed world, but their impact in developing countries like India have been on lower side. The major problems are; breeding programs have been too complex in terms of logistics, technology and other resources without considering the infrastructure required, indiscriminate crossbreeding of indigenous breeds with exotic breeds without enough consideration of environmental conditions for production, lack of plans on how to maintain a suitable level of 'upgrading' or on how to maintain the pure breeds for future use in crossbreeding contribute to non-sustainability, need of proven sires, poor spread of artificial insemination facilities, small sized herds, high cost of data recording, differences socio-economic and cultural roles that livestock play in each situation, usually leading to wrong breeding objectives and neglecting the potentials of various indigenous breeds of livestock and requirement of comprehensive approaches to design simple yet effective breeding strategies in low-input environments[20,29].

LIVESTOCK POPULATION DYNAMICS

On a global scenario the total number of breed records in the Global Databank has increased greatly since the publication of the WWL–DAD: 3 (World Watch List – Domestic Animal Diversity), total increment of entries was from 6,379 (December, 1999) to 14,017 (January, 2006), including the increment in avian species (from 1,049 to 3,505) and mammalian species (from 5,330 to 10,512)[11]. According to FAO[11], of the total world's population of domestic livestock in different categories, 97% buffaloes, 32 % cattle, 62 % goat, 36 % sheep, 62 % pig and 48% chicken population is found in Asia. India being one of the largest agriculture based economy has a significant contribution in these proportions and as per the Basic Animal Husbandry Statistics[4]; 14.7 % cattle, 57.3 % buffalo, 6.8% sheep, 16.7% goat, 1.9% camel and 4.5% chicken population of the world is found in India. However, most of the domestic livestock, about 87%, is distributed among marginal, small and semi medium farmers, i.e., 50.1 %, 21.6 % and 15.9% respectively with a very small land holding capacity of, below 1 to 3.99 hectare [4]. Therefore, planning a breeding strategy for improvement of such diverse and scattered population of livestock is a major challenge with conditions getting worse with increasing inflation and cost of animal rearing and data recording. Hence, a comprehensive breeding structure is required that could fulfill the expectations of animal breeder without being too technical & expensive, the open nucleus breeding system proposed by Cunnigham addresses most of these issues with added flexibility to incorporate the modern biotechnological tools for increased production, if available.

OPEN NUCLEUS BREEDING SYSTEM

The basic idea of Open Nucleus Breeding System (ONBS) using Multiple Ovulation and Embryo Transfer (MOET) is to set an elite herd (or a few elite herds) of males and females and carry out intensive selection and testing within herd/s selecting males and females at an early age using family information and not on their progenies as in the case of the Progeny Testing Programme or just on their parents as in the case of pedigree selection (www.nddb.org).

According to Nicoll[19], a nucleus breeding scheme is based on the principle that in each herd there is a small number of genetically very superior animals which if brought together will form a nucleus whose average genetic merit is far greater than that in any of the contributing herds. To increase the overall genetic merit of the breed nucleus breeding systems are used. Cooperative breeding system (nucleus) was alternative to traditional breeding system which based on principles as Farmers record their herd top female send them to one unit forming nucleus managed by farmers committee open highly productive female selected males used as replacement in the cooperating farms In these, the group of farmers was agreeing to pool their high performing animals. The best males were kept for breeding in nucleus while other selected males were given to the base herds for breeding. The nucleus remained open to animals from the base herds and the best females from the latter being admitted periodically and compared with those in the nucleus. Only females were transferred from the base to the nucleus. So, genetic superiority of sire replacement coming into base from nucleus was greater than base herds. Nucleus herd breeding schemes where the selection of breeding stock is concentrated in a few herds from which the selected animals are spread to other herds, are attractive in many developing countries[26, 27]. They are designed to allow a good recording on a limited number of animals and data management at reasonable cost and may be combined with the use of efficient reproduction technologies. Open nucleus breeding schemes (ONBS), which also allow inflow of high potential breeding animals from other herds, have been proposed as ideal for genetic improvement in situations with moderate levels of management [26, 27, 3]. A nucleus herd programme is used to both conserve an indigenous breed and to upgrade the local population. The plan operates around a central herd which should preferably be under government control and carry out proper recording and breeding practices. The supporting base population is the village herds which provide cows to replace about 10 percent of the cows in the central herd annually (in case of dairy cattle). Selection from village herds is done by simple procedures involving visual judgment, milking ability, size, conformation and condition[7].

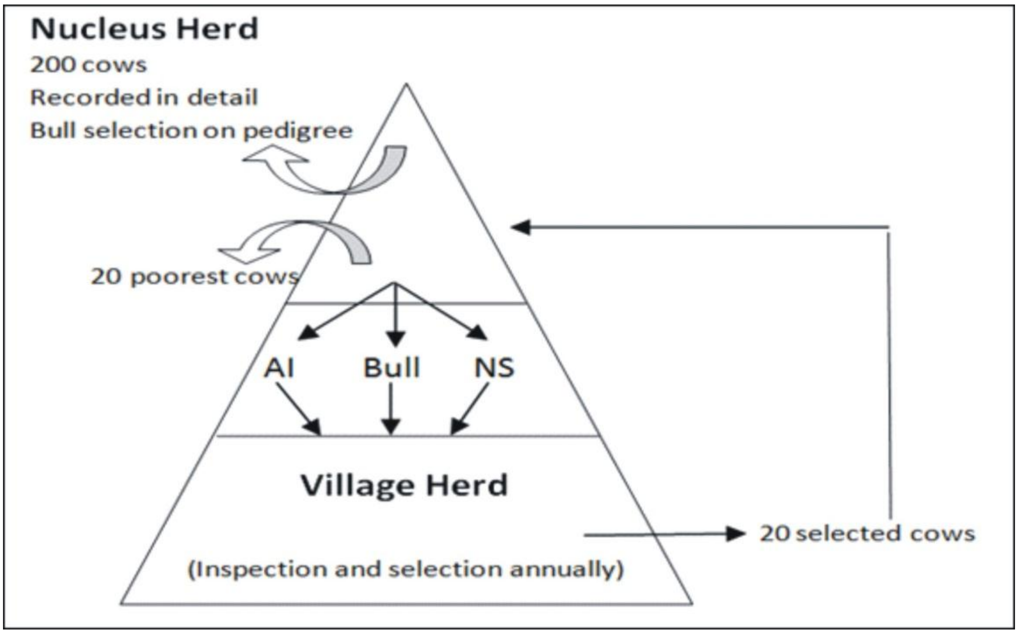

Fig. Open nucleus breeding scheme (Cunningham, 1979)

According to Richard Bourdon, Nucleus Breeding System is a cooperating breeding programme in which elite animals are concentrated in nucleus herd/flock & superior germ plasm has then distributed among cooperative herd/flock to nucleus. Nicholas[18] gave a typical breed structure consists of 3 tiers in the shape of pyramid. Roden[22] classified ONBS in two classes called closed and open according to the replacement Stock.

As in the traditional pyramid, there was one way flow of genes, downward from top to bottom in Closed Nucleus System. Source of cumulative genetic progress in commercial population was improvement occurs in the nucleus populations. Rate of inbreeding increased and overall genetic gain fluctuate[18]. This can be observed mainly in Pig & Poultry. Rate of inbreeding in ONBS = 2 CNBS[12]. In case of Open Nucleus Breeding System, the gene flow from both way viz., downward from nucleus to other lower herd (multiplier & commercial) and upward from lower to upper herd (nucleus) by introduction of superior animals from other herds. Rate of inbreeding reduces and genetic progress increases as superior animals were available with farmers. This kind of breeding system can be observed only in Cattle, Buffalo, Sheep and Goat[18].

The ONBS can be useful in the developing countries where herd or flock size is small. ONBS can lead to a 10-15% increase in annual response to selection which substantially reduce the rate of inbreeding in the nucleus[18]. Shortest generation interval.

Principal Factors:

1. Nucleus Size: - Optimum nucleus size is a function of the ratio of selection intensities in males and females (James, 1976). In cattle and sheep populations the highest rate of genetic gain was achieved when nucleus size has 5-10% of the population[12]. As female selection intensity decreased and male selection intensity increased, the optimum nucleus size decreased[12]. At smaller nucleus sizes more generations are required (Muller and James, 1983).

2. Migration Rate: - According to Shepherd (1991), migration rate vary over selection period to maximize the response. Upward female migration rate was favoured long time if short-term selection response was to be maximized.

Optimization of ONBS Structure is required to maximize genetic gain and financial returns. Criteria for Optimization: - Rate of Inbreeding Effective population size of nucleus Genetic gain Economic returns.

Models of ONBS:

1. Jackson & Turner Model [1972] - Evaluate various structure in ONBS Gene flow and genetic differences between base and nucleus population Genetic selection differential Annual genetic gain.
2. James Model [1977] - System operate over two tiers. Truncation Migration rate constant over time , genetic lag & annual rate of genetic gain to constant equilibrium values. Effective size of population = 2 [size of nucleus]
3. Hopkins & James Model [1977]- Overlapping generations Discrete generation Parental selection/Sequential culling Migration rate optimizing genetic selection differential [never fixed overtime] Similar model used in Dairy Cattle.

In this scheme, gene flow is both ways viz. downward from nucleus to other lower herd & upward from lower herd to upper herd (nucleus) by introduction of superior animals from other herds, maximum rate of gain can be achieved when 5-10% of the nucleus female replacement comes from the contributing small herds. Hence a breeder can achieve greater rate of improvement (up to 15- 25%) because of high selection intensity[2,12]. The main advantage of ONBS is that it can be incorporated with small as well as commercial farmers by utilizing the exceptional animals from both of them that might go unnoticed or unrecorded, such an animal can form a part of the nucleus herd and with the use of artificial insemination technique such animals can be utilized to infuse fresh blood (or genes) to the nucleus herd, hence such a system allows flexibility in introduction of new genes from outside sources, keeping the nucleus herd rejuvenated. Another advantage of open nucleus is that it allows quick improvement in genetic mean of existing nucleus[30].

Since the merit of males is judged on the basis of performance of their sisters and half-sisters – referred to as sibling test and not on the performance of their progenies, the generation interval is considerably reduced. Although, the accuracy of selection under sibling test is lower than that achieved in the progeny test, the benefits of reducing the generation interval outweighs the loss of accuracy. The genetic response under a well-run ONBS could be as high as that is achieved under the conventional progeny-testing programme. As selection and testing is done within a herd or in a few herds, the greater degree of control on the determinants of genetic change i.e. intensity of selection, generation interval and accuracy of selection is possible (www.nddb.org).

Simulation studies in mid 1990s underscored the usefulness of open nucleus breeding system in large & small ruminants, selection for live body weights in lamb in open nucleus breeding system showed higher rate of genetic gain, more predictable selection response and lower rates of inbreeding than closed nucleus system[22]. A theoretical analysis of nucleus breeding systems showed that the rate of genetic gain may be increased by 10 to 15% in sheep and beef cattle breeding with keeping the rate of inbreeding to about half of that in closed nucleus system[12]. Therefore a variety of open nucleus breeding programs were recommended and some were implemented during 1990s (FAO, 1992; Mutetwa and Makuza, 1996; Etse, 1999; Yapi-Gnoare, 2000). Overall higher genetic merit through ONBS is expected (3-5%) in comparison to traditional livestock breeding system (0.5%). An application of ONBS in breeding Egyptian water buffaloes has been illustrated by Abdel-Salam et al., (2010) with a conclusion that applying open nucleus breeding scheme (ONBS) for many generations of selection could accelerate the rate of genetic gain of milk production and increase the average milk yield by 15% in G1 (Generation 1) to 26% in G4 (Generation 4). ONBS scheme is able to address many issues important in developing countries (e.g. individual herds are very small, difficult data recording & controlled mating etc.). For the dissemination of genetic progress from the ONBS to be effective, a very high chance of the superior breeding males mating with the breeding females must be ensured and full participation as well as long-term commitment of the livestock keepers with institutional/ nucleus herds must be ensured[17]. Through ONBS, it is possible to record data on feed convertion efficiency, reproduction efficiency, disease resistance, body confirmation etc. which are not easy to record in progeny testing programmes. It hold the promises to enhances milk production as well as socioeconomic status of farmers.

MULTIPLE OVULATION & EMBRYO TRANSFER WITH ONBS (MOET-ONBS)

In order to take maximum advantage of AI techniques, animal breeders proposed and successfully implemented progeny testing schemes, which have been the standard procedure for genetic evaluation in dairy cattle for more than 30 years. Multiple ovulation embryo transfer (MOET) is a technology which includes super ovulation, fertilization and embryo recovery, short-term in vitro culture of embryos, embryo freezing and embryo transfer. It is beneficial as it increases the number of offspring produced by elite females (hence most advantageous in case of large ruminants) and hence it can be used in increasing the population of rare or endangered breeds, in ex situ preservation of animal genetic resources, progeny testing of females and increasing rates of genetic improvement in breeding programmes[21]. ONBS was also accompanied with multiple ovulation and embryo transfer (MOET) which maximize the annual genetic gain[8].

To increase the rate of genetic response in dairy cattle MOET nucleus schemes used[18]. MOET augment reproductive potential of donor female & formed embryo transferred to recipient which are of low genetic gain. In elite herd of male & female Generation interval is reduced for reason of sibling test for selection which lower the accuracy of selection. Controlled environment is maintained as selection & testing is done in nucleus herd. Development of MOET technology enables to increase reproductive rate of cow. MOET are relevant where Progeny Test schemes are not feasible. High selection intensity is applied to females which make shortest generation interval. MOET in ONBS is used as an alternative to conventional progeny testing for evaluation of bulls and bull mothers.

The first authors to study the impact of incorporating MOET into selection programs were Land and Hill[14], in beef cattle & concluded that rate of response should double with incorporation of MOET. Nicolas & Smith[18], proposed use of MOET in hierarchical breeding structure in dairy cattle. Thus MOET provide a way to increase the genetic gain through ONBS. Success of any MOET programme depends on efficient experimental protocol, more number of females in nucleus herd with higher reproductive and embryo transfer success rates[5] and in reduction of generation interval by obtaining more number of offsprings from a single elite female[13]. MOET has an added advantage that rate of twinning can be increased by embryo splitting, desired sex can be produced by embryo sexing, more number of progeny per animal can be obtained without inversing the nucleus herd size, offsprings can be obtained from elite cows having some disease or injury and the females can be progeny tested for harmful recessive genes. MOET schemes are of three basic types; (1) Juvenile MOET (selection of bulls and cows is done at early age before breeding), the generation interval in this scheme is less; (2) Adult MOET (selection of males and females is done in adult stage at different criteria), generation interval in this scheme is longer than juvenile MOET; (3) Hybrid or mixed MOET (males are selected by PT). Colleau[6] concluded that the overall potentiality of hybrid MOET is likely to surpass that of conventional schemes. Schrooten and Van Arendok[23] in a simulation study underscored the benefit of MOET in open nucleus breeding scheme, they reported that the annual genetic progress in MOET – ONBS was 4-6 % higher as compared to classical progeny testing schemes and this response was reduced to 1-2% when the nucleus was closed. A similar finding has been reported by Dimov and Dimitrov[7] in buffaloes, where they reported an increment of 50 % in genetic gain when MOET-ONBS programs are combined with progeny testing scheme as compared to progeny testing alone. A significant work on feasibility & efficiency of MOET has been carried out in India also, which shows the effectiveness of MOET and MOET-ONBS in improvement of indigenous livestock population[28, 24, 8]. Because of small & scattered population and risk of inbreeding it was suggested that ONBS schemes (in combination with MOET, wherever available) will be best suited for genetic improvement of livestock in Indian conditions[25].

CONCLUSION

Genetic improvement schemes followed for large animals in developed countries are often difficult to apply in developing countries[26, 27]. For a livestock population such diverse & organized in small flocks, as in India, there is a need to develop breeding system that suits the local livestock rearing practice with simultaneous assimilation of modern reproductive biotechnological tools. Open nucleus breeding system provides an approach that addresses these issues in effective and relatively less technical means. It offers two way gene flow it also offers conservation of genetic resources & upgrading of local population. ONBS (in combination with MOET) allows higher selection intensity in females, increases the number of viable offspring that can be obtained from a single elite female, therefore reducing the generation interval & maximizes response per generation, utilizes the potential of nucleus as well as associated small herds & transmits the genetic improvement in a two way process, from the nucleus to the associated herds and vice versa, therefore it allows more rapid improvement with limited resources & data recording, which is practically most suitable for developing countries.

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