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Comparison of Breeding Scenarios in Open Nucleus Breeding System for Genetic Improvement of Iranian Native Buffaloes (*Bubalus bubalis*)

Research Article

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ABSTRACT

This study was aimed to compare the open nucleus breeding systems for Iranian buffaloes (*Bubalus bubalis*). To compare the genetic gain and inbreeding variations, three levels of nucleus size (5, 10, and 15), three levels of male transfer rate from the nucleus to commercial (0.25, 0.5, and 0.75), and two levels of female transfer rate from commercial to the nucleus (0.25 and 0.5) were simulated by QMsim software. Comparing different strategies, genetic improvement declined with the increase of the nucleus population in the total population. Our results showed that the optimal combination of total genetic value improvement and inbreeding was obtained for scenarios of the open nucleus breeding strategy with 10% herd size, 75% male transfer rate from the nucleus to commercial, and 25% female transfer rate from commercial to the nucleus. Results confirmed that describing breeding goals, determination of an appropriate selection index, and considering open nucleus breeding systems along with optimal scenarios of male and female transfer between the nucleus and commercial herds, can lead us to genetic improvement as well as reduced inbreeding, and thereby development in the traits performance of Iranian buffaloes.

KEY WORDS genetic gain, Iranian buffalo, open nucleus breeding strategy, stochastic simulation.

INTRODUCTION

Buffalo farming in Iran plays an important role in the national economy, the availability of food for society, and providing job opportunities (Borghese, 2005; Ghavi Hossein-Zadeh, 2017; Safari *et al.* 2018). Adaptation to changes in the environment, limited feed and water resources, and also the food demand of rapidly growing human population are important reasons for maintaining native and adaptive populations such as buffalo, as a competitive breed (Thornton, 2010). Considering the significant role of buffalo farming in providing the income and necessities of the rural population in Iran, three breeding stations have been established to promote buffalo production efficiency through the identification of genetic potentials, breeding, and artificial fertilization techniques. At these stations, male buffaloes are selected from the commercial herds and after various tests, the superior male animals were selected at the village level and applied for artificial fertilization (Borghese, 2005; Manafiazar *et al.* 2009; Safari *et al.* 2018). The main reasons for the lack of breeding programs for native livestock are small herd-size, and the absence of recording systems for productive, reproductive, and functional traits (Wasike *et al.* 2011). Determination of breeding goals for small systems in harsh environments needs to ensure the sustainability of the breeding program.

Selection goals are defined based on improving the economic efficiency of the production system by considering the numerous influencing factors including financial status, pricing policy, production costs, and other factors (Kariuki *et al*. 2014). Designing a breeding program for selecting the superior animals in which the genetic merit is maximized is one of the essential issues in the breeding program. Open nucleus breeding strategy (ONBS) offers a convenient procedure to produce and disseminate known breeding values (Cunningham, 1987). In the ONBS, the superior animals of commercial herds are transferred to the nucleus. The transfer of superior individuals in both directions can increase the rate of genetic improvement and reduce the inbreeding rate in comparison to the closed state (Bondoc and Smith, 1993). Several studies indicated the significance of applying the ONBS to increase the rate of genetic gain (Dixit and Sadana, 1999; Abdel-Salam *et al*. 2004; Nigm *et al*. 2005). The purpose of this study was to simulate different strategies to evaluate the effects of population size, nucleus size, and the number of transferred females from commercial to nucleus towards increasing total genetic value in open nucleus breeding strategy in Iranian buffaloes.

MATERIALS AND METHODS

The simulated population resembled the dispersed breeding nucleus of Iranian buffalo (Figure 1). In the first stage, a population of 500 individuals was simulated as the historical population. The random mating was implemented in the system for 50 generations to allow the population to evolve until it reached the equilibrium between mutation and random genetic drift due to finite population size. To reach a balanced mutation-drift population, the population size increased from 500 to 10000 after 100 generations. The reference population was sampled randomly from the population of the 100^{th} generation to construct the initial founders after 30 generations. Finally, the Iranian buffalo population was simulated based on the population structure of the buffalo herds in Iran (Safari *et al*. 2019). A total of 5000 females and 250 males were considered. Commercial and nucleus groups were created for 10 generations (Figure 1).

Different scenarios were evaluated regards to sensitivity of results to change in population size, the number of base males born in the nucleus, and the nucleus female born in the base. Populations were randomly simulated in 20 repetitions using QMSim software (Sargolzaei and Schenkel, 2009). A wide range of parameters to the production of accurate data is considered by the software.

The population was considered as four-way and included two commercial and nucleus groups. The commercial and nucleus groups were established for 10 generations to observe the effect of selection on increasing genetic variance. Three population sizes were considered as 5, 10, and 15%.

Superior females were selected from the base herds each year and entered to nucleus herd. Superior individuals were selected based on the best linear unbiased prediction (BLUP) on QMsim software and random mating system. In this study, genetic parameters estimated by Ghavi Hossein-Zadeh (2017) were used for the milk production trait. The male transfer rate from the nucleus to base was used at 0.25, 0.5, and 0.75. The female transfer rate from base to nucleus was also used at 0.25 and 0.5 (Table 1).

Total genetic value and inbreeding coefficient were selected for each generation and calculated in 20 repetitions for each selection scenario. Different strategies were implemented for 10 generations and 20 repetitions. The average 20 repetitions were considered the result of the strategy, and genetic, phenotypic, and inbreeding values were calculated. The regression analysis was used to investigate the relationship between the dependent variable (genetic and value and inbreeding) and the independent variable (generation) over 10 generations using the R program (R Development Core Team).

RESULTS AND DISCUSSION

The total genetic values obtained from different strategies are presented in Table 2. The results showed that the highest genetic value was in 10% nucleus size, base males and females born in the nucleus were (X)= 0.75 and (Y)= 0.25, respectively. Genetic improvement decreased by increasing the nucleus population in the total population. In a breeding strategy, genetic improvement is influenced by population size, nucleus to total population ratio, the transfer rate between nucleus and base populations, structure and composition of the population, and generation interval between nucleus and base (Mueller and James, 1983). Changing the base male born in the nucleus transfer rate (X) made the genetic value increased along with the elevation of the X parameter. However, genetic value was decreased by increasing the X values. The minimum of the genetic value in all nucleus sizes was obtained for X= 0.25 and Y= 0.5.

At the 5% nucleus population size, the highest genetic value was related to the strategy with X= 0.75 and Y= 0.5, and the regression coefficient of genetic improvement per generation was b= 0.25. The difference between the optimal strategy of this population size and other strategies was significant ($P \geq 0.05$).

When population size increased from 10% to 15%, the genetic value of the strategies elevated, and the highest genetic value was at X= 0.75, however, the difference between the strategies was not significant in this population size. It could be concluded from the results that for all strategies, the increasing transfer rate of superior males from the nucleus to base increases the genetic gain in the total population significantly.

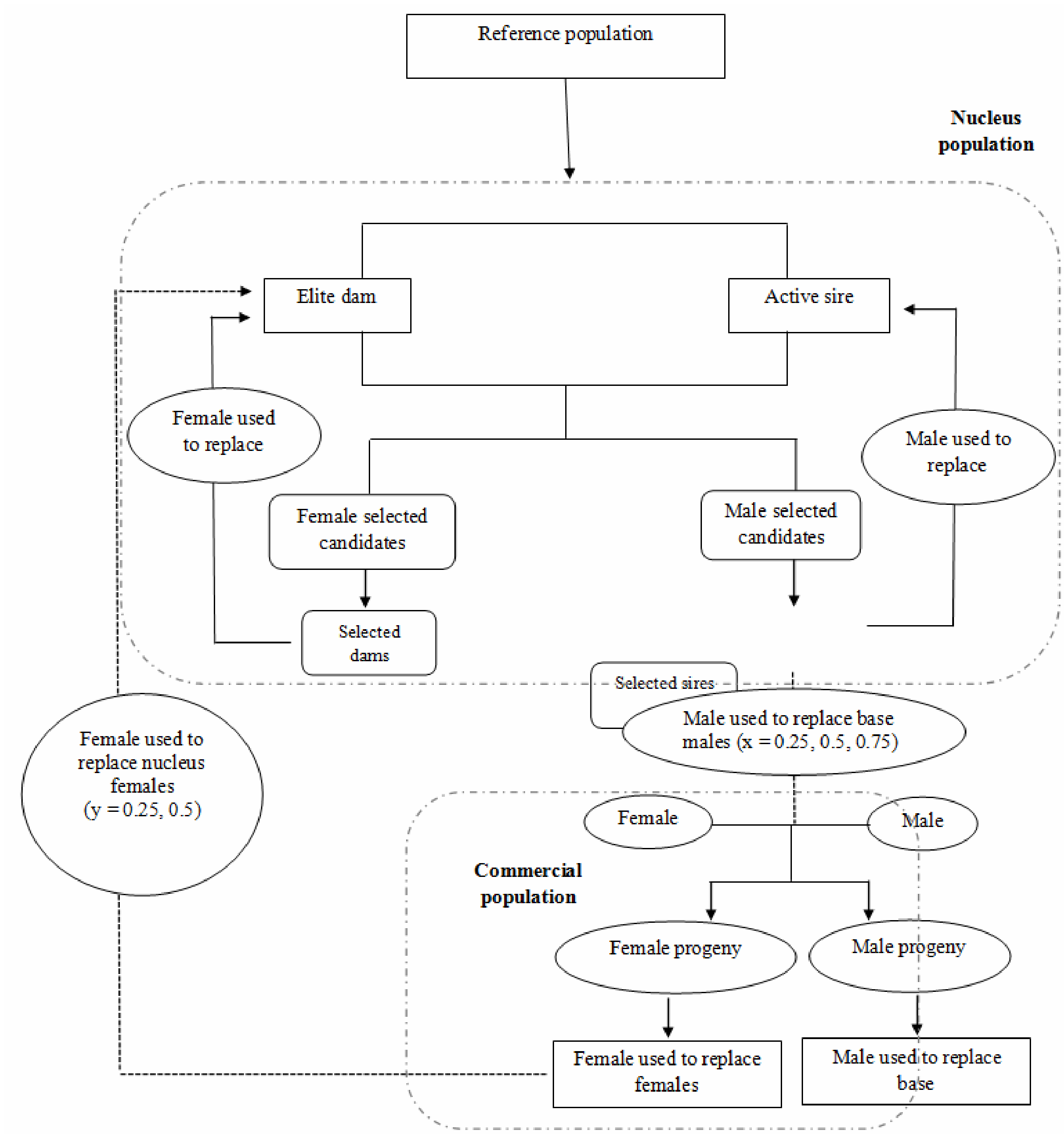

Figure 1 Structure of stochastic simulation

Table 1 Information for the open commercial nucleus strategy of Iranian native buffaloes (*Bubalus bubalis*)

Traits	Value
Heritability	0.46
Probability of male/female of progenies	50%
Number of generations	10
Number of replicates	20
The proportion of male progeny	0.5
Ratio of nucleus population to total population (%)	5, 10, 15
Fraction of commercial male born in nucleus	0.25, 0.5, 0.75
Fraction of nucleus dams born in commercial	0.25, 0.5
The proportion of sire replacement	0.4
The proportion of dam replacement	0.25
Selection design	BLUP
Estimated breeding value	BLUP
Mating system	Random

BLUP: best linear unbiased prediction.

The decline in the genetic improvement with the increasing number of generations was due to the reduction in genetic difference between the nucleus and base populations. It means that the genetic differences between the nucleus and base populations decreased with increasing generations. Ebrahemian *et al*. (2012) studied the nucleus strategies in Moghani sheep and reported that the optimum condition was obtained in X= 0.75 and Y= 0.25, which is consistent with our results. As shown in Table 2, increasing values of X and Y resulted in a change in the selection intensity of females and males in the nucleus and base population. However, this change in nucleus and base populations had opposed direction. Increasing X made a decrease in the selection intensity of transferred males from the nucleus to base, also the selection intensity of transferred nucleus females born in base showed a decline. However, the growing nucleus size leads to an increase in keeping prices. If nucleus females were selected from commercial and nucleus herds, alternatively, the larger nucleus herds were less superior compared to the commercial herd. Thus, the genetic improvement prompted increasing nucleus fraction from the total population, which resulted in the differences between nucleus and base populations.

The regression coefficient of genetic improvement was 0.28 for 14.83 ± 1.16 total genetic values. The results showed that the genetic value means had an increasing trend with higher generations for all population sizes. Dixit and Sadana (1999) studied OBNS in Moore buffalo and they reported that the optimal nucleus size, number of nucleus dams born in the base, number of base dams born in the nucleus (Y), base sires born in the nucleus, and number of males used as a parent were 0.1, 0.40, 0.10, and 0.01, respectively. They observed the genetic gain was 140.81 kg milk per generation or 24.36 kg milk per year. Abdul Salam *et al*. (2004) reported that ONBS could accelerate the rate of genetic gain of milk production in Egyptian buffalo and increase the average milk yield. The genetic gain for each generation was significantly increased due to the change of nucleus size from 0.1 to 0.5. In this study, the average genetic improvement in optimal strategy increased from 6.57 in the first generation to 14.87 in the 10th generation. The highest rate of genetic gain (38%) was observed between the first and second generations and the lowest ones, as 7% were between 7^{th} and 8^{th} generations (Abdul Salam *et al.* 2004). Taheri Dezfuli and De Seno (2016), in a study on Khuzestan buffaloes using computer simulation, reported that the 30-years of direct selection program on milk trait had positive effects on genetic and phenotypic traits, however, was negative for protein and fat percentage because of negative genetic correlation between these two traits with milk yield.

Nigm *et al*. (2005) studied ONBS to improve milk production using computer simulation, in three populations of Egyptian buffaloes. They investigated the effect of the combination of population size, nucleus size, and the number of nucleus females born based on genetic improvement and they found that genetic improvement in each generation was in the range of 139 to 186 kg, and genetic improvement annually was in the range of 24.1 to 32.1 kg of milk per year. As pointed out by Seno *et al*. (2012), in the Brazilian buffalo population, financial genetic improvement and genetic trends in phenotypic selection and test-results increased with the cumulative number of herds in the recording scheme.

The results of phenotypic value and inbreeding for different nucleus sizes in the open nucleus system are presented in Table 3. As shown in Table 1, by changing of Y, variations in the phenotypic value followed from the observed pattern in genetic value. Phenotypic value for 10% nucleus size with X= 0.75 and Y= 0.25 showed the highest value. The minimum phenotypic value was at 5% nucleus size with X= 0.25 and Y= 0. 5. These results showed that an increase of nucleus size and the number of females entered the nucleus leads to a decrease in phenotypic value in the simulated population. The inbreeding coefficients for different nucleus sizes in different strategy are shown in Table 4. Results indicated that the highest extent of inbreeding was obtained for inbreeding from 5% nucleus size with X= 0.25 and Y= 0.25.

These results showed that increase in nucleus size and the number of females entered the nucleus leads to an increase in inbreeding value in the simulated population. On the other hand, the lowest inbreeding was observed in 15% nucleus size. Also, the reduction of nucleus size and the number of males due to higher interbreeding between populations resulted in improvement in inbreeding, genetic and phenotypic values. Increased homozygosity was associated with a decline in genetic diversity, which in turn reduced genetic improvement.

Increasing population size from 5% to 10% resulted in a 75% decrease in inbreeding. An increase in the transfer rate of males from the nucleus to commercial herds and also the transfer rate of females from the base to the nucleus, the inbreeding rate was decreased. It can be noted that the average weight of the family in the selection index could be decreased, which can reduce the selection of relatives and thus decrease the inbreeding (Verrier *et al*. 1993).

The inbreeding rate had an increasing trend in all strategies over 10 generations. Its highest level was observed for the strategy with X= 0.25 and Y= 0.25 in 5% population size, which elevated from 0 in the first generation to 0.16 in the 10th generation.

Table 2 Total genetic value for open nucleus system at different sizes of nucleus population in Iranian native buffaloes (*Bubalus bubalis*)

Nucleus size	X	Y	Total genetic value (Mean±SD)	Regression coeffeicient of genetic value per generation
0.15	0.25	0.25	13.5±1.3[c]	0.23
		0.5	12.561±0.98[c]	0.24
	0.5	0.25	13.155±2.1[b]	0.22
		0.5	13.668±1.2[b]	0.24
	0.75	0.25	14.306±1.1[a]	0.22
		0.5	14.3493±1.11[ab]	0.21
0.1	0.25	0.25	14.205±0.87[ab]	0.24
		0.5	13.131±0.98[ab]	0.21
	0.5	0.25	14.163±0.66[ab]	0.23
		0.5	13.263±0.57[ab]	0.24
	0.75	0.25	13.601±1.12[ab]	0.25
		0.5	14.83±1.16[a]	0.28
0.05	0.25	0.25	10.931±1.17[b]	0.19
		0.5	10.112±1.13[b]	0.24
	0.5	0.25	10.996±1.14[b]	0.23
		0.5	9.923±1.15[b]	0.2
	0.75	0.25	11.700±1.12[a]	0.25
		0.5	11.982±1.7[ab]	0.22

X: commercial male born in nucleus transfer rate and Y: nucleus female born in commercial transfer rate.
SD: standard deviation.

Table 3 Phenotypic value and inbreeding for different nucleus sizes of Iranian native buffaloes (*Bubalus bubalis*) in the open nucleus system

Nucleus size	X	Y	Total Phenotypic value (Mean±SD)	Inbreeding
0.15	0.25	0.25	14.5±1.3	0.017
		0.5	13.561±0.98	0.027
	0.5	0.25	13.755±2.1	0.032
		0.5	13.918±1.2	0.038
	0.75	0.25	14.606±1.1	0.046
		0.5	14.893±1.11	0.061
0.1	0.25	0.25	14.219±0.014	0.04
		0.5	13.845±0.013	0.052
	0.5	0.25	14.156±0.011	0.041
		0.5	14.157±0.273	0.06
	0.75	0.25	14.621±0.011	0.071
		0.5	14.356±0.149	0.082
0.05	0.25	0.25	12.231±1.17	0.16
		0.5	12.912±1.13	0.11
	0.5	0.25	11.996±1.14	0.09
		0.5	10.923±1.15	0.087
	0.75	0.25	11.700±1.12	0.093
		0.5	10.982±1.7	0.067

X: commercial male born in nucleus transfer rate and Y: nucleus female born in commercial transfer rate.
SD: standard deviation.

The Regression coefficient of inbreeding per generation and regression coefficient of inbreeding per genetic gain was 0.003 and 0.04 in this strategy, respectively. Mating system and the selection programs are deciding about the choice a pair of a candidates in order to maximize the genetic improvement and minimize inbreeding. Therefore, ideally, mating and selection should be performed in the way of optimization of genetic gain and inbreeding.

Various optimization routines have been proposed for the balance between genetic improvement and inbreeding (Colleau *et al.* 2009; Pryce *et al.* 2012).

As seen in Figure 2, in the strategy with the greatest inbreeding (X=0.25, Y=0.25), inbreeding coefficient increased significantly across generations. These findings are consistent with the results of other studies (Meuwissen, 1997; Malhado *et al.* 2013; Ghavi Hossein-Zadeh, 2015).

Table 4 Regression coefficient for inbreeding per generation and regression coefficient of inbreeding per genetic gain in different strategies for Iranian native buffaloes (*Bubalus bubalis*)

Nucleus size	X	Y	Regression coefficient of inbreeding per generation	Regression coefficient of inbreeding per genetic gain
0.15	0.25	0.25	0.003	0.02
		0.5	0.004	0.01
	0.5	0.25	0.001	0.03
		0.5	0.005	0.02
	0.75	0.25	0.003	0.01
		0.5	0.005	0.02
0.1	0.25	0.25	0.001	0.020
		0.5	0.003	0.03
	0.5	0.25	0.004	0.04
		0.5	0.001	0.05
	0.75	0.25	0.003	0.04
		0.5	0.004	0.03
0.05	0.25	0.25	0.003	0.04
		0.5	0.007	0.03
	0.5	0.25	0.006	0.02
		0.5	0.005	0.03
	0.75	0.25	0.003	0.03
		0.5	0.004	0.04

X: commercial male born in nucleus transfer rate and Y: nucleus female born in commercial transfer rate.

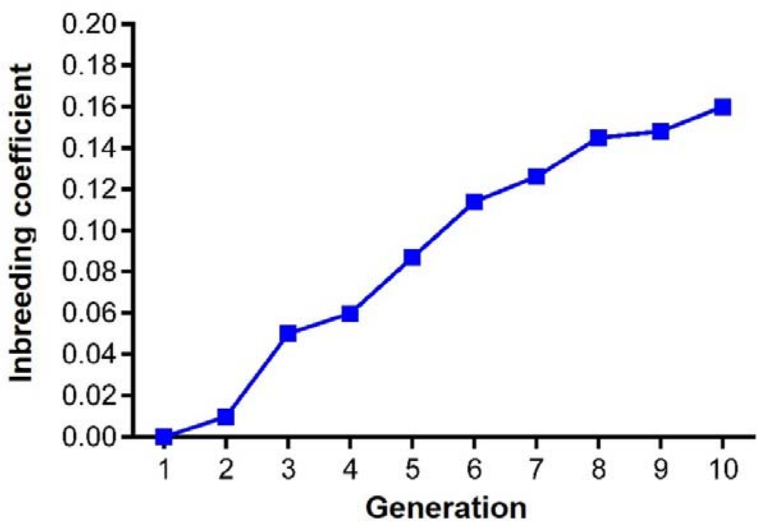

Figure 2 Trend of changes in inbreeding coefficient of Iranian native buffaloes (*Bubalus bubalis*) across generations

It is worth noting that open nucleus systems have greater genetic and economic efficiency in comparison to the closed nucleus systems (Shepherd and Kinghorn, 1992). ONBSs have some advantages. These provide selection in a large population, reduce the risk of inbreeding, and result in more significant genetic improvement than the closed nucleus (James, 1978; Shepherd and Kinghorn, 1992).

In breeding systems, genetic gain and response to selection are not only criteria for evaluation, since inbreeding as an indicator of variation within animals also has a crucial role. A high level of inbreeding could reduce traits performance, and lead to loss of diversity which is an important role to compare breeding systems.

Based on Alderson (2009) system, the levels of risk defined according to some criteria; population (number of dams), geographical location (radius, Km), and genetics (predicted inbreeding in the following 25 years). Finally, if the average of inbreeding was greater than 10% in the next 25 years, the population will be considered at risk. Controlling inbreeding can be a significant issue in a limited-scale population. Conservation of animal genetic resources, control of inbreeding, and protection of genetic diversity benefit from genetic management of population through the design of proper breeding programs.

CONCLUSION

The absence of effective sustainable breeding programs for local breeds in developing countries is a reason that such breeds fail in their competitive advantage. In this study, the ONBS offers a useful scheme for the estimating the breeding values in *Bubalus bubalis*. Using the selected generations in an open nucleus system improves the genetic gain of milk trait and increases the average milk production quantity in Iranian buffalo. Designing appropriate breeding programs at a largescale, selection of proper strategies, identification of policies and legal instruments related to the supporting infrastructure, as well as providing operational plans, to improve traits performance and profitability of native buffaloes, should also be considered in Iran.

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