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OPTIMAL BREEDING PROGRAMS FOR LAO NATIVE GOATS IN SMALLHOLDER SYSTEMS

S.V. Le[1], S. de las Heras-Saldana[2], P. Alexandri[2] and J.H.J. van der Werf[1]

[1] School of Rural & Environmental Science, University of New England, Armidale, NSW, 2351 Australia
[2] Aninal Genetics Breeding Unit*, University of New England, Armidale, NSW, 2351 Australia

SUMMARY

This study used stochastic simulation to evaluate breeding strategies aimed at improving body weight of Lao native goats in smallholder systems while maintaining genetic diversity. Simulation reflected both traditional breeding practices and alternative strategies, including random mating, selection on phenotype, and rotational mating scenarios at herd and village level. After 20 mating cycles, traditional practices (random mating at herd level) resulted in limited body weight improvement and a high inbreeding level (0.216). Selection and rotational mating showed improvement in body weight while also affecting inbreeding level. The rotation strategy achieved the highest body weight gain (1.2 phenotypic standard deviation, PSD, units) and a relatively low inbreeding level (0.071). The genetic gain and inbreeding levels were 0.899 PSD and 0.077, respectively, for village-selection and 0.69 PSD and 0.24, respectively, for herd-selection. Overall, rotational mating significantly increased the body weight while maintaining low inbreeding, making it a promising breeding strategy for Lao farmers. For successful implementation, this approach will require pedigree and animal performance recording and active farmer participation.

INTRODUCTION

Genetic improvement of indigenous livestock provides an important strategy to improve the living standard of farmers in developing countries. Lao native goats play an important role in the livelihoods of smallholder farmers, contributing up to 46% of total household income (Walkden-Brown *et al*. 2024). Like other indigenous breeds, Lao native goats have small body sizes and a slow growth rate but they are adapted to local environments and management practices. These goats are primarily raised in smallholder systems with herd sizes ranging from 1 to 37 goats (Walkden-Brown *et al*. 2024). Based on spatial data, Le (2024) observed that goats in Laos graze on communal lands or are kept on private property, with males used either from their herd or exchanged with other herds. Some gene flow was detected between herds both within and across villages (Le *et al*. 2023; Le *et al*. 2024). Currently, no formal breeding program has been introduced or implemented for Lao native goats in smallholder systems and farmers lack systematic evaluation of productivity (Gray *et al*. 2019). Several studies have explored different breeding strategies for smallholder systems, the cooperative village or village-based breeding programs (CBBPs) closely align with the observed management practices in Laos (Gizaw *et al.* 2014; Le 2024). To assess the potential of CBBPs in this context, we simulated various breeding scenarios in which sires and dams were selected either randomly or based on an observed phenotype for body weight. These sires were used either within their herds or exchanged with other herds within and between villages. When sires are selected from the same herd or different herds, females could be mated with siblings or relatives, which would increase the inbreeding rate. The objective was to identify the most effective breeding programs for improving body weight while maintaining genetic diversity in smallholder systems, providing recommendations to Lao farmers on sustainable breeding practices.

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MATERIALS AND METHODS

Breeding objective. Lao native goats have a small body size and are bred for meat production. Kids are light at birth weighing between 1.1 to 1.5kg and reach 9.7kg at weaning at around 3 months of age. Traders, abattoirs and restaurant owners offer higher prices to Lao farmers when their goats reach 20kg weight at around a year old (Walkden-Brown *et al*. 2024). As a result, Lao farmers are increasingly motivated to improve the productivity of their goats by enhancing their body weight to meet the growing demand from traders exporting to Vietnam (Walkden-Brown *et al*. 2024).

Breeding scenarios. Different breeding scenarios were simulated in R using a custom script to reflect both traditional breeding practices and alternative strategies at herd and village levels. The base population for each herd contained 22 unrelated animals (20 females and 2 males) and 20 females were mated to one of two males in the two mating rounds thereafter, with an average of two progeny per female per mating, ranging from 1 to 3 offspring. Each village had three herds. The simulation ran for 20 mating cycles, assuming a 50:50 sex ratio among offspring. The total number of animals simulated for one breeding program at the herd and village level was therefore 822 and 2,466, respectively. The herd of the offspring was assigned based on the herd of their dams. Starting from the third mating cycle, the mating strategy varied depending on the specific breeding scenario. Each breeding scenario was replicated 1,000 times to track patterns of genetic gain and inbreeding level.

Heritability (h^2) for body weight was set at 0.2, with offspring survival from birth to mating age at 0.8 and dam survival after each mating round at 0.9. Phenotypes were sampled as the sum of the breeding value and a random residual effect, with variance equal to h^2 and ($1-h^2$), respectively. The phenotypic variance was assumed to be 1 and $\sigma_a^2 = h^2$. Breeding values in the base population were sampled randomly for N(0, σ_a^2), whereas breeding values in subsequent generations were simulated as a parental average breeding value with an additional Mendelian sampling term. The variance due to Mendelian sampling decreased with increased inbreeding (Van der Werf and De Boer 1990).

$$\mathrm{var}(\Phi) = \frac{1}{2}[1 - \frac{1}{2}(F_s + F_d)]\sigma_a^2$$

where $\mathrm{var}(\Phi)$ is a variance of the trait; F_s and F_d are inbreeding coefficients for sire and dam, respectively; σ_a^2 is the additive genetic variance before selection.

From the third mating cycle onward, dams and sires were selected either randomly or based on their phenotype, depending on the breeding scenario. For each herd, two male offspring from the (*i* - 2) mating cycle were selected, while 20 dams were selected from the dams of the (*i* – 1) mating cycle and the female offspring from the (*i* – 2 mating cycle) (Figure 1). Mating occurred either randomly or in a rotational system, depending on the scenario.

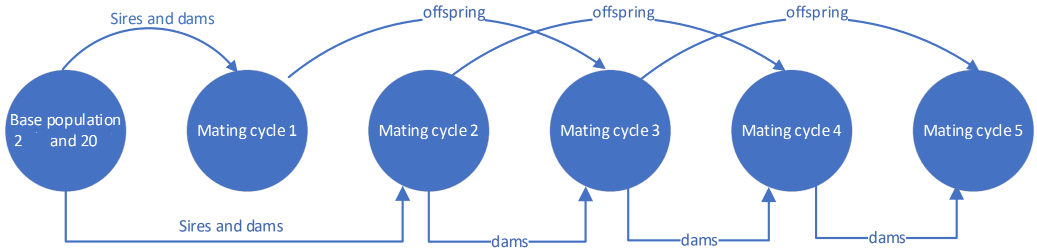

Figure 1. The diagram of the first five mating cycles for herd mating breeding scenarios

Definition of the breeding scenarios. *Herd-random.* Sires and dams are randomly selected in a herd and they are mated randomly.

Herd-selection. Sires and dams are selected based on their phenotype for each herd. The two heaviest sires and 20 heaviest dams are mated randomly.

Village-random. This was a simulation for three herds within a village, and sires and dams were randomly selected. From the third mating cycle, two sires and 20 dams were selected randomly from each herd and these six sires were randomly allocated to these 60 females.

Village-selection. This was similar to village-random, but sires and dams are selected based on their phenotype.

Village-rotation. This was similar to village-selection. Instead of random mating, a mating rotation was applied, where selected males from herd 1, herd 2, and herd 3 were mated with selected females in herd 2, herd 3, and herd 1, respectively.

Data analysis. In each breeding scenario, the body weight improvement was calculated as the average body weight across all the animals born from each mating cycle and then averaged across 1,000 replicates. Similarly, the inbreeding coefficient was averaged over all progeny born in each mating cycle, and then averaged across 1,000 replicates.

RESULTS AND DISCUSSION

The changes in body weight and inbreeding level of simulated Lao native goats over 20 mating cycles at herd and village levels are displayed in Figures 2A and 2B, respectively. In terms of breeding strategies, the rotation approach led to the greatest improvement, followed by selection, while random mating showed little effect on body weight. The maximum bodyweight improvements achieved after 20 mating cycles were for; village-rotation 1.2 PSD units, village-selection 0.9 PSD units, herd-selection 0.69 PSD units, herd-random 0.26 PSD units, and for village-random 0.108 PSD units.

Although the inbreeding levels increased in all breeding scenarios, the inbreeding levels for both breeding scenarios at herd level were higher than those at village level. The rate of inbreeding at the 20th mating cycle for herd-selection and herd-random scenarios were 0.24 and 0.216, respectively, while the inbreeding levels at village levels were 0.077, 0.071, and 0.029 for selection, rotation, and random mating strategies, respectively.

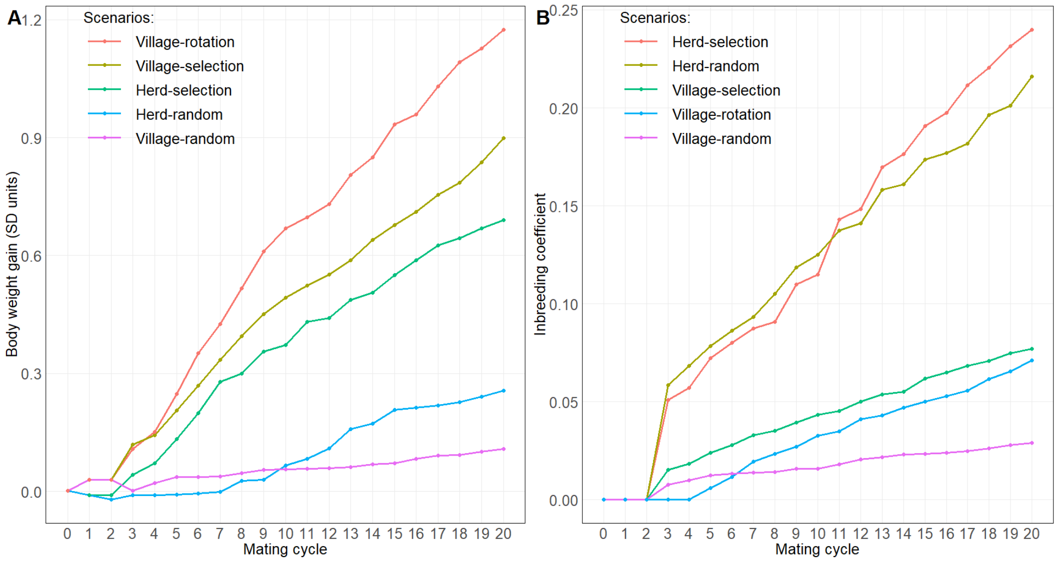

Figure 1. Average body weight gain (A) and inbreeding level (B) across mating cycles under all breeding scenarios

The rotational program at the village level appears to be a promismng strategy to improve the bodyweight of Lao native goats while maintaining a low level of inbreeding. For practical implementation, rotational breeding within a village or between villages could form a foundation for genetic improvement.

The findings in this study were in alignment with previous studies. For example in Ethiopia, Gizaw *et al.* (2014) reported significant genetic improvement in Menz sheep in village breeding programs, with birth weight and weights at three and six months increasing by 0.49 to 2.46 kg after three generations. Similarly in Sudan, Omer *et al.* (2022) found the highest genetic gain in milk yield performance of Butana cattle under the rotational use of bulls between herds compared to the use of herd bulls.

Lao farmers mainly rely on local grass and fodder to feed their goats (Gray *et al*. 2019). However, feed availability is characterised by seasonal shortages, low nutritional content and limited energy and protein (Xayalath *et al*. 2021). Supplementation is rarely practised in smallholder systems (Walkden-Brown *et al*. 2024). Therefore, improving the genetic potential for weight gain in Lao native goats must be accompanied by forage production initiatives and supplementary feeding practices. Additionally, since Lao goats typically graze on communal lands for 6 to 8 hours daily and bucks are generally uncastrated (Walkden-Brown *et al*. 2024), the implementation of a rotational breeding strategy requires specific management adjustments. Breeding bucks should be kept separate, and non-breeding bucks castrated to prevent undesired mating.

Future studies could explore more advanced genetic evaluation tools involving a larger number of herds per village, such as Best Linear Unbiased Prediction (BLUP), and genomic BLUP, to estimate the breeding values of economically important traits for Lao goats. Genetic improvement can also be achieved through within-breed selection or crossbreeding with exotic breeds. Boer goats or Bach-Thao goats are available in Laos; however, there is limited documentation on their performance and development in the region. Further studies should evaluate the effectiveness of crossbreeding strategies to improve the productivity of Lao native goats.

CONCLUSION

Lao native goats have small body sizes, and traditional breeding practices in Laos showed minimal body weight improvement over time while increasing the inbreeding rate. A rotational mating strategy, an alternative breeding program that involves selecting bucks based on phenotype ranking and exchanging them between herds, could improve the body weight of Lao goats while maintaining genetic diversity.

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