Alternative Models of Genetic Evaluation of Reproductive Traits for Local Goat Population under Arid Conditions

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Abstract: The success of small ruminant breeding programs depends on appropriate models for genetic evaluation of traits showing a genetic association between reproductive phenotypes. The study aims to determine the environmental and genetic components that synthesize the reproductive performance of local goats in arid conditions, in order to make the foundations for future genetic improvement of this population. Two reproductif traits were studied: the interval between kidding and the litter size at birth. Three models were used for each case, univariate and bivariate analyzes which differ in random effects included in the model, only the additive genetic effects, only the permanent environmental effects or both effects simultaneously. The obtained results suggest that the Bi-variate model including only the permanent environmental effects of the goat is the most adequate to model the reproductive performance of local goat. Direct genetic variances are mainly higher using the uni-variate model than the Bivariate model. The environmental variance estimates obtained are the same for both models. The heritabilities recorded from the uni-variate model are slightly lower than the estimates from the Bi-variate model. It seems imperative to consider in animal model, all the genetic and environmental effects, that intervene on the determinism of reproductif traits.

INTRODUCTION

Local breeds are often used because of their adaptation to the harsh conditions but they are characterised by a small body weight and slow growth which impairs economic profit[1]. Genetic improvement of growth ability and fertility traits of local breeds would enhance the economic benefit of goat farming in this area. Currently, the absence of improvement plans for this population represents a loss in genetic progress which would help the prosperity of this sector[2]. It is therefore urgent to apply selection methodologies appropriate to the characteristics of this population and its environmental. In addition, the selection schemes are based on certain genetic parameters, the estimation of which is an essential step for the development of selection tools and for identifying candidate traits for selection. Heritability is a key genetic parameter that indicates the percentage of superiority or inferiority that parents are likely to pass on to their offspring[3, 4]. The success of small ruminant breeding programs depends on appropriate models for genetic evaluation of females by verifying the presence of a genetic association between different reproductive traits. The repeatability model assumes that reproductive traits in different environments are characterized as repeated measures of the same trait[5]. Many small ruminant breeding programs still use this model, although, the genetic basis for these traits may differ with each kidding[6]. Najari[2] proposed a selection scheme within pastoral goat herds by considering the individual numerical productivity of 3 years of breeding as selection criteria for mother goats. This improvement objective makes it possible to increase the meat productivity of suckler dams. The positive correlation between reproductive potential and adaptation ensures the maintenance, or improvement of the capacities of the local population through an improvement plan. The aim of this study is to determine the environmental and genetic components that synthesize the reproductive performance of local goats under arid conditions in order to lay the foundations for future genetic improvement of this population. Two reproductive traits: Kidding Interval (KI) and Litter Size at Birth (LSB) were considered as quantitative measures of local goat fertility as they represent two main components of reproductive performance.

MATERIALS AND METHODS

Location: All studied animals belong to the goat experimental herd of the Arid Areas Institute of Médenine Tunisia (33°30‘N and 10°40’E) which is located in Southeastern Tunisia (Fig. 1), between the mountains of Matmata and the Mediterranean Sea. This region is characterized by an arid continental Mediterranean climate with irregular precipitations with an average annual rainfall of about 200 mm. The summer is normally the hottest and driest season with a maximum temperature of 47°C[1].

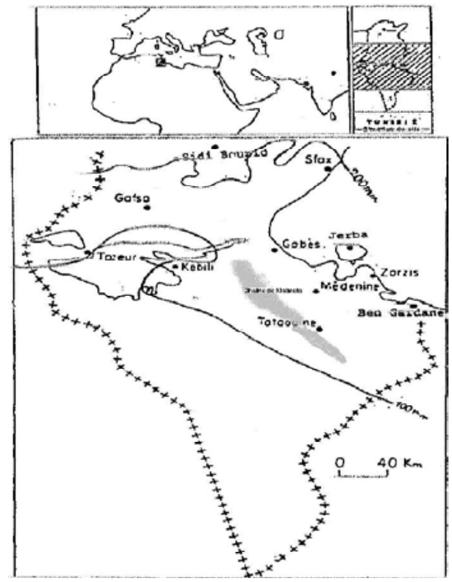

Fig. 1: Location of the study area

Animal and management: The Tunisian local goat population is very polymorphic[2] but it is generally characterised by its small body size with average height of 76 cm for the male and 60 cm for the female[7]. The goats participating in this study were raised in the Arid Areas Institute of Medenine (IRA), in the South-East of Tunisia with an arid continental Mediterranean climate with irregular and sporadic rain. Records of 462 kiddings produced from mating of 11 sires to a total number of 185 goats between 1992 and 2014 were used for this study. Animals were mated following a breeding system of one kidding per year. The main mating period was from June to August which corresponds to births in autumn. If a doe was not pregnant during the first mating period, it was transferred to the group that was mated at the next mating period (October-November which corresponds to births in spring). The female kids were mated for the first time between 12 and 18 months of age, depending on their birth season. The number of goats mated per sire in a mating season varied from 5-17. The season of kidding begins in October and continues until February with a concentration during November and December. Goats were randomly assigned to bucks. Bucks were changed every 5 years with replacements coming from outside flocks. Bucks were also selected from the experimental flock on the basis of weaning weight and good conformation. Does were mated to the males after weaning their kids[1].

Traits analyzed: Two variables, Kidding Interval (KI) and Litter Size at Birth (LSB) were considered as measures of goat’s fertility, since, they represent two main components of the reproductive performance.

Statistical analyses: For each trait, the variance components were estimated on the basis of three models and which were used for each case, univariate and bivariate analyzes which differ by the random effects included in the model, only additive genetic effects (Eq. 1), only permanent environmental effects (Eq. 2) or both effects simultaneously (Eq. 3). The fixed effects included were: the interaction year×month of kidding, parity and age of goat at kidding.

The first model adopted includes the following fixed effects: interaction year×month of kidding, parity and age of goat and a direct genetic effect of the goat. The model has been written in general matrix form:

$$y = Xb+Z1ad+e \tag{1}$$

Where:

y	=	Vector of reproductive performance (univariate or bivariate one or two-trait analysis, respectively)
ad	=	Vector of the direct genetic effects of the goat
e	=	Vector of the residuals
b	=	Vector of fixed effects
X, Z1	=	Incidence matrices

The second equation adopted includes the following fixed effects: interaction year×month of kidding, parity and age of goat and a permanent environmental effect of goat. The equation has been written in general matrix form:

$$y = Xb+W1pd+e \tag{2}$$

Where:

y	=	Vector of reproductive performance (univariate or bivariate one or two-trait analysis, respectively)
pd	=	Vector of permanent environmental effects
e	=	Vector of the residuals
b	=	Vector of fixed effects
X, W1	=	Incidence matrices

The third model adopted includes the following fixed effects: interaction year×month of kidding, parity and age of goat, a direct genetic effect of goat and a permanent environmental effect of goat. The equation has been written in general matrix form:

$$y = Xb+Z1ad+W1pd+e \tag{3}$$

Where:

y	=	Vector of reproductive performance (univariate or bivariate one or two-trait analysis, respectively)
ad	=	Vector of direct genetic effects in the goat
pd	=	Vector of permanent environmental effects
e	=	Vector of the residuals
b	=	Vector of fixed effects
X, Z1, W1	=	Incidence matrices

Selection models and estimation of genetic parameters: The equations were compared by testing the -2logL and the Akaike Information Criterion (AIC). The equation with lower values of -2log L and lower AIC is considered the best. The estimation of the genetic parameters was carried out using the REML method of the BLUPf90 programs[8] by considering the variance homogeneous. From the analysis models, the estimated genetic parameters are direct heritability and the other components which are additive genetic variance, permanent environment variance; residual variance; phenotypic variance.

RESULTS

Reproductive performance of local goats: The reproduction performances of the local goat are presented in Table 1 and which are cited by Atoui *et al.*[1]. The KI mean estimated in this study was 13.85 months with a coefficient of variation of 38%. The does had kidding intervals which varied from 9.04-37.83 months. The mean for LSB obtained in this study, 1.33 was lower than that of some world prolific goat breeds including Nubian, Pygmy, American Alpine, French Alpine, Saanen and Toggenburg with the average litter size of 2.0, 1.9, 1.9, 1.7, 1.7 and 1.6, respectively.

Selection models: Two models uni and Bi-varié were used for the evaluation of reproductive characteristics of local goats. The description of the models with the corresponding -2LogL and the AIC information criteria were presented in Table 2.

The Bi-variate Eq. (2) presents the low value of AIC (Table 2) which suggests that this model is the most suitable for modeling the reproduction performance of local goat population. The Bi-variate Eq. (3) was the worst model of all equations considered for the two criteria.

Influence of the analysis model on the estimation of genetic parameters: Estimates of variance components

Table 1: Descriptive statistics for reproductive performance of local goats[1]

Variable	KI (months)	LSB (kids born)
Minimum	9.04	1.0
Maximum	37.83	3.0
Mean	13.85	1.33
SD	5.20	0.49
CV (%)	38.00	37.00

SD = Std. Deviation; CV = Coefficient of Variation

Table 2: Comparison criteria between the reproduction performance of local goat population

Models	-2logL	AIC
Univariate models		
1	2622.3	2630.3
2	2619.47	2627.47
3	2618.49	2630.49
Bivariate models		
1	2618.09	2630.09
2	2615.44	2627.44
3	2614.13	2632.13

AIC = Akaike's Information Criterion; -2logL = The log likelihood

Table 3: Variance components and heritability estimates of reproductive traits in local goat population

Modèles	σ^2_a KI	σ^2_{pe} KI	σ^2_a LSB	σ^2_{pe} LSB	h^2_d KI	h^2_d LSB
Univariate models						
1	5.071	0	0.074	0	0.152	0.31
2	0	3.862	0	0.07	0	0
3	3.832	2.122	0.018	0.053	0.115	0.078
Bivariate models						
1	5.802	0	0.075	0	0.173	0.314
2	0	4.012	0	0.07	0	0
3	4.025	2.12	0.019	0.053	0.12	0.081

σ^2_a = (Additive genetic variance); σ^2_{pe} = (Permanent environmental variance), h^2_d = (Direct heritability); KI = (Interval between two kidding); LSB (Litter Size at Birth)

and genetic parameters for reproductive traits obtained from the different models were shown in Table 3. Direct genetic variances were mainly higher using the uni-variate model than the Bi-variate equation. The magnitude of the environmental variance of LSB is minimal; it is about the half of the value obtained for direct genetic effect. The estimates of environmental variance were the same for the two models (uni and bivariate). The estimates of direct genetic variances (case of the uni-variate Eq. 3) were 3.832 and 0.018, respectively for KI and LSB. The heritability estimate of LSB (0.31).

For all equations, direct genetic variance component for KI were quite similar with univariate or bivariate models as expected from scale effects. Direct geneticl variance estimates for LSB were generally lower with Eq. 3 than Eq. 1. Univariate and bivariate models (Eq. 1) showed similar direct heritability. For environmental effects, Eq. 3 tended to yield smaller estimates of permanent environmental variance.

DISCUSSION

The reproduction performances of local goat population show a heterogeneous potentialities under pastoral conditions (Table 1). The average performances was low but justifiable for animals adapted to arid conditions. Thus, a slight effort to improve breeding conditions, associated with a selection program appropriate to this adapted genetic resource and its arid environment, will help to get higher production and reproduction levels.

Mean KI was considerably higher than other estimates in literature[3], for Black Bengal goat and Roy *et al.*[6], for Saanen goats). The waiting period of around 5 months (when kids are with their mothers) to mate goats after kids are weaned may explain the larger KI in this population.

A relatively small litter size might be a direct result of the long natural selection process under arid conditions. In fact, the local population must have a productive behavior coherent with the local resources on rangelands and the pastoral extensive breeding system. The likely reduced dairy performance does not allow feeding more than one or two kids per year. Thus, local goats' reduced litter size represents a genetic adaptation to natural environment of pastoral breeding in arid regions[2, 1].

The estimates of direct genetic variances (case of the uni-variate Eq. 3) were in agreement with the literature[9]. Similar and low estimates (2.832 and 0.053 for KI and LSB, respectively) of phenotypic variances have been reported by Land[10].

The heritabilities estimates from the uni-variate model were slightly lower than those obtained from the Bi-variate equation. The h^{2d} estimates obtained by the Bi-variate equation (Eq. 3) are 0.12 and 0.081 for KI and LSB, respectively. These values are in agreement with the estimates reported by Land[10]. The heritability estimates for KI was 0.12 with this model. This result appears to be greater than 0.04 reported by Odubote[11]. Singh *et al.*[3] mentioned that the low heritability estimates for KI may be attributed to the low quality of pastures on which the flock was maintained, not allowing for a full expression of the reproductive potential resulting in a high environmental variance.

The heritability estimate of LSB (0.31) obtained in this study (with the Bi-variate model "1" is in agreement with the results of Devendra[12] for the Alpine goat in France and the Bengal black goatin India[9] for Zaraibi goats in Egypt. Land[10] found an average of 0.1 in sheep. Bradford pointed out that heritability of LSB is quite low and, summarizing over 30 estimates for different breeds and methods of estimation, reported a range from 0.15-0.35. Thus, any change in the components of the variance will change the estimate of heritability. This could explain the differences in the estimates of heritability obtained in different studies.

Estimates of heritability for reproductive traits in this study were moderately low indicating that accurate selection based on doe's own performance to improve these reproductive traits will require information from a large number of kiddings[1]. In the next stage, the traits which could be used as selection criteria to indirectly improve doe reproductive traits should be investigated. The low estimates of heritability for reproductive traits indicated the presence of large environmental variances. More studies and larger data bases are needed to identify the true genetic behavior of such genetic resources for these environments, especially to make inference about the genetic correlation between the two reproductive traits. In order to optimize the reproductive potential of the local goat population, it is essential to adopt an appropriate reproductive management program addressing the most important individual traits which are directly involved in increasing lifetime productivity.

CONCLUSION

It seems essential to consider in animal model, all the genetic and environmental effects which intervene on the determinism of reproductive traits in local goat population. Thus, the choice of analysis model is decisive for a good estimation of genetic parameters. The genetic variability detected in the studied population allows to hold expectations for the implementation of selection programmes for fertility traits in this local breed.

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