Spanish Journal of Agricultural Research
16 (2), e0404, 7 pages (2018)
eISSN: 2171-9292
https://doi.org/10.5424/sjar/2018162-12604
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, O.A, M.P. (INIA)

RESEARCH ARTICLE

OPEN ACCESS

Evaluation of a local goat population for fertility traits aiming at the improvement of its economic sustainability through genetic selection

Ahlem Atoui[1], María J. Carabaño[2] and Sghaier Najari[1]

[1]*Institute of Arid Regions, Faculty of Sciences (F.S.G), University of Gabés, Médenine 4119, Tunisia.* [2]*INIA, Dept. de Mejora Genética Animal, Ctra. de La Coruña Km 7.5, 28040 Madrid, Spain.*

Abstract

The study aims to determine the environmental and genetic components for the reproductive performance of a Tunisian local goat population to set up the basis for the future improvement of this important component of efficient production. The reproductive traits considered were kidding interval (KI) and litter size at birth (LSB). Records of 462 kiddings belonging to 185 dams and 11 sires were collected over a period of 22 years in the caprine herd of the Arid Areas Institute of Médenine. Significance of environmental effects was tested with ANOVA techniques. Genetic parameters were estimated using restricted maximum likelihood fitting an animal mixed model. Mean KI and LSB were 13.85 ± 5.20 months and 1.33 ± 0.49 kids, respectively. The effect of parity number and the interaction between year and month of kidding were significant for LSB and KI. Trait LSB increased with parity number up to the fifth parity while KI decreased with parity number indicating that young females show compromised reproductive performance probably because of growth requirements and scarcity of food resources. A detrimental effect for kiddings occurring during winter (matings in summer) was observed from estimates of the year by month of kidding effect. Heritability estimates for KI and LSB were 0.13 and 0.08, respectively. A moderate repeatability estimate of 0.31 was obtained for LSB while 0.17 was obtained for KI. The low estimates of heritability obtained for reproductive traits indicated that accurate selection based on the doe's own performance will require large amounts of data. However, the estimated genetic variability was substantial, providing the grounds for the genetic improvement of the reproductive parameters in this population.

Additional keywords: local goats; kidding interval; litter size at birth; genetic parameters.

Abbreviations used: KI (Kidding Interval); LSB (Litter Size at Birth).

Authors' contributions: All authors contributed in design, data analysis and drafting the manuscript.

Citation: Atoui, A.; Carabaño, M. J.; Najari, S. (2018). Evaluation of a local goat population for fertility traits aiming at the improvement of its economic sustainability through genetic selection. Spanish Journal of Agricultural Research, Volume 16, Issue 2, e0404. https://doi.org/10.5424/sjar/2018162-12604

Received: 20 Nov 2017. **Accepted:** 25 Jun 2018.

Funding: The authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

Correspondence should be addressed to Ahlem Atoui: ahlematoui@gmail.com

Introduction

Reproductive efficiency is always considered to be the most important factor ensuring increase in productivity for certain environmental conditions (Hossain *et al.*, 2004). Increased production efficiency can be obtained from goats since they have a high reproductive efficiency with the potential for increased litter size and shorter generation interval in comparison to other farm animals (Safari *et al.*, 2007). On the other hand, the goats' reproductive performance is an indicator of their adaptation to adverse conditions. Reproduction (understood as the ability to produce viable offspring) is a complex composite trait influenced by many components including puberty, estrus, ovulation, fertilization, pregnancy, parturition, lactation, and mothering ability. The level of reproductive performance of goats is dependent on genetic and environmental factors, but this performance is particularly sensitive to the latter (Song & Sol, 2006). Herd management, year, season and parity were some of the factors that affected fertility in different studies (Safari *et al.*, 2007).

Although local goat populations are expected to show a goodability to accommodate and adapt to fluctuations in environment, this often involves some degree of reproductive failure (Najari, 2005). This is the case of the Tunisian local breed of goats (Najari *et al.*, 2007) and other local breeds raised under extensive or semi-extensive conditions in arid areas (Chukwuka *et al.*, 2010).Genetic improvement programmes for these breeds are little developed and many times rely on crossing practices that do not yield the expected results, particularly in the reproductive component of productivity (Najari *et al.*, 2007). Selection in local populations could have a major impact in the improvement of the economic benefits and sustainability of local goat farms.

Identification of superior animals and subsequent selection decisions should be based on genetic merit rather than on differences due to environmental effects. Developing effective genetic evaluation and improvement programs requires knowledge of the genetic parameters and environmental effects that need to be adjusted for in economically important traits. These parameters need to be estimated from relevant populations as parameters and fixed effects may vary among breeds and different populations (Safari *et al.*, 2007).

Information of environmental effects and genetic parameters in local populations under harsh conditions, such as Southern Tunisia are scarce since performance recording is difficult under extensive conditions and due to the lack of organizations of performance recording. A goat experimental herd of the Arid Areas Institute of Tunisia has been recording reproductive performance of the local goat population for the last two decades, providing valuable information for studying the potential of a reproductive selection scheme in a local breed. Therefore, the purpose of this study was to determine the environmental and genetic components for the reproductive performance of a Tunisian local goat population raised under extensive and climate harsh conditions to set up the basis for the future improvement of this important component of efficient production.

Material 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, 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 (Ouni *et al.*, 2007).

Animals and management

The Tunisian local goat population is very polymorphic (Najari, 2005), but it is generally characterized by its small body size with average height of 76 cm for the male and 60cm for the female (Ouni *et al.*, 2007). This local goat breed is famous for its walking ability, resistance to hydric restrictions and high temperature stress and good productivity in harsh conditions.

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 to 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.

The identities of newborns and their parents, date of mating, date of kidding, sex of kid, litter size and parity of does were recorded. For each individual under study a record sheet with full details of each parameter along with pedigree information were maintained. New-born kids were allowed to suckle their does and were left with them up to 5 months of age.

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

The significance of fixed effects of year and month of kidding, age of dam, parity and their first order interactions was tested using the ANOVA procedure of the Statistical Package of Social Sciences (SPSS.20). Significant means were separated using the Duncan's multiple range test.

A two-trait animal model, where the significant effects from the ANOVA analyses were included to correct for environmental factors, was used. The model used was:

$$y_{ijklm} = YM_i + P_j + b\,(AGE) + a_k + pe_l + e_{ijklm}$$

where, y_{ijklm} was the observation for each trait; YM_i was the fixed effect of the interaction between year and month of kidding; P_j was the fixed effect of the j[th] parity (j= 2, 3,…, 9); b was a fixed regression coefficient of y on age of the goat in which the measurement was observed (AGE); a_k was the random additive genetic effect of goat; pe_l was the permanent environmental effect of goat; and e_{ijklm} was the random residual term.

The effects of animal, permanent environmental and residual were assumed to be random factors with zero means and variances $\mathbf{A}\otimes\mathbf{G}_0$, $\mathbf{I}\otimes\mathbf{P}_0$ and $\mathbf{I}\otimes\mathbf{R}_0$, where **A** was the additive relationship matrix, **I** was identity matrixand $\mathbf{G}_0$, $\mathbf{P}_0$ and $\mathbf{R}_0$ were co-variance matrices of the two traits for additive genetic, permanent environmental and residual effects, respectively. Variance components and associated genetic parameters, together with solutions for position parameters were estimated under a Bayesian approximation using the Gibbsf90 programme of the BLUPf90 family of programmes (Misztal *et al.*, 2002). A total of 200,000 samples with 50,000 used as burn-in were obtained to get the posterior distributions of the parameters of interest.

Solutions for genetic effects from the previous model were used to obtain genetic trends. Averages by year of birth of the estimated genetic values were plotted against year of birth and a linear regression line fitted to obtain estimates of genetic progress per year.

Results and discussion

Summary statistics for KI and LSB are provided in Table 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 to 37.83 months. Mean KI was considerably higher than other estimates in literature (Singh *et al.*, 2002, for Black Bengal goat; and Roy *et al.*, 2007, 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.

The litter size proportions for simple and multiple births were 67.7% and 32.3%, respectively. 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 (Amoah *et al.*, 1996). 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 (Najari, 2005).

Table 1. Basic statistics for female reproductive traits of Tunisian local goats.

Variable	KI (months)	LSB (kids born)
No. of records	462	462
Minimum	9.04	1
Maximum	37.83	3
Mean	13.85	1.33
SD	5.20	0.49
CV (%)	38	37

SD: std. deviation; CV: coefficient of variation

Fixed effects

Table 2 shows the results of the ANOVA analyses to test the significance of the year, month and parity number effect on K and LSB. Effect of the year-month interaction was significant for the two traits. This effect is especially due to the variations of climate, food nutritional quality and herd management along time. Present findings were also in partial agreement with the finding of Alexandre *et al.* (2001) in Creole goats.

Fig.1a shows seasonal patterns for KI, indicating that the worst reproductive results are obtained with goats kidding in the winter season (December-January) which would correspond to matings in July-August. This is meaning that the harsh summer conditions affect the fertility of females, both by high temperature peaks and food scarcity. Under our breeding pastoral mode, where kids are not weaned, a late kidding month means a milking period until the following mating period in summer, and these tardive goats may have serious problems to ensure fecundation under non favorable

Table 2. Test of significance from ANOVA analyses and coefficient of determination (R^2) of a model including non-genetic factors on reproductive traits of local goats.

Sources of variation	DF	KI	LSB
Year*Month	45	*	**
Parity	7	**	**
R^2	-	0.63	0.62

KI: kidding interval, LSB: litter size at birth, DF: degrees of freedom; *,**: significant ($p<0.05$, $p<0.01$, respectively).

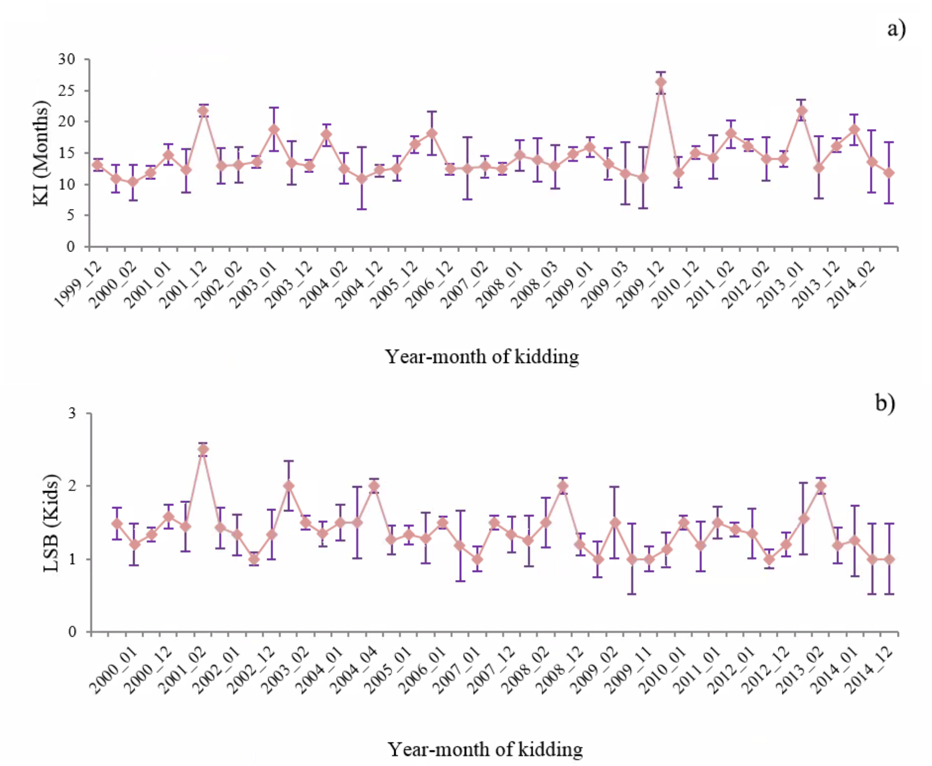

Figure 1. Least square means and standard deviation (bars) for goat's kidding intervals (KI in a) and litter size at birth (LSB in b) among year-month interactions during 14 years.

endocrine and body condition profile. Thus, the local breeders tend to reduce the kidding period to the early winter. Overall, apart from the seasonal differences, KI showed a stable trend along years.

The trend of the effect of kidding month on LSB is shown in Fig.1b. The highest values are observed for does kidding in spring, which corresponds to matings occurred in October -November. Our findings were in agreement with those of severa1 authors (Güney *et al.*, 2006; Mellado *et al.*, 2006) who found that kidding season has a significant effect on reproductive traits. According to some authors (Mellado & Meza-Herrera, 2002; Chemineau *et al.*, 2004), reproductive traits in goats and sheep varied mainly with the photoperiod. As for KI, apart from the seasonal variations, LSB shows a stable trend across the period of 14 years. The lack of a steady trend in the reproductive traits along time indicates that no improvements in the environment have been practiced in this population for reproductive traits.

Fig. 2 shows the effect of parity number on both traits. A large value of KI was observed for the second parity and then, it tended to decrease. Similar results were found by other authors (Odubote *et al.*, 1992; Greyling, 2000; Song, 2003; Hamed *et al.*, 2009). An explanation of the larger KI for parity 2 is that goats are still growing and need more energy for this purpose. If resources are scarce, there may be a negative energy balance and production is delayed. For LSB, there seems to be a general increase as parity progresses up until the fifth parity. This may be due to improved efficiency of reproduction as the goat matures (Song, 2003).

Variance components and heritability estimation

Estimated variance components from the two-trait REML analyses are presented in Table 3. According to the results shown in this table; heritability estimates of those traits are rather low. Low heritability estimates of reproductive traits are mainly due to the greater proportional influence of environmental effects, since genetic variation seems to be significant. According to the obtained estimates for the additive genetic variance, the expected values of the progeny of the best and worst animals according to their genetic values (assuming two standard deviations around the mean) could differ in up to 8 months for KI and 0.54 kids for LSB. Thus, enough genetic variability exists to practice selection.

The estimate of KI heritability was 0.12. This result was higher than 0.04 reported by Odubote (1996) and lower than 0.30 obtained by Nahardeka *et al.* (1995). Singh *et al.* (2002) mentioned that the low heritability estimates for KI may be attributed to the low quality of pastures on which the flock was maintained, not

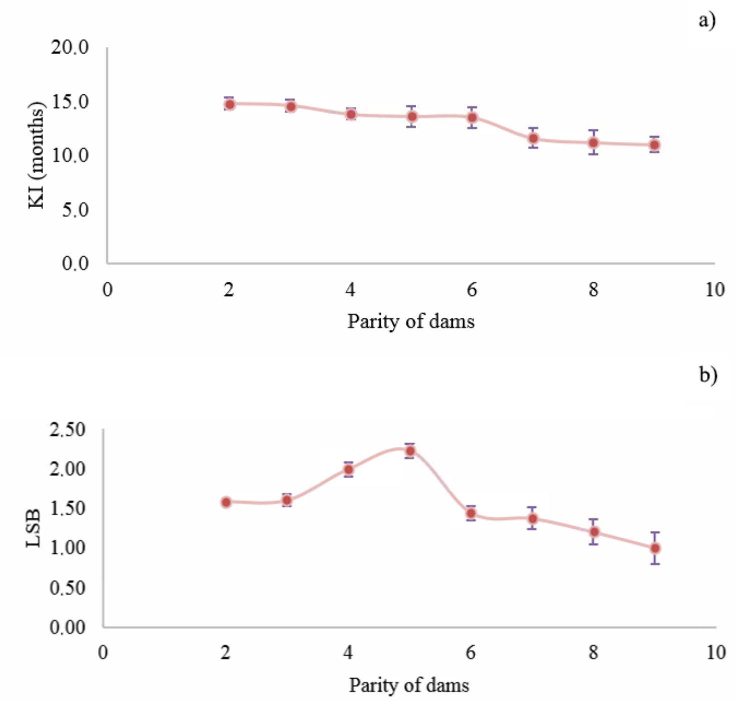

Figure 2. Least square means and standard deviation (bars) for parity effect on goat´s KI (a) and LSB (b).

allowing for a full expression of the reproductive potential resulting in a high environmental variance.

Heritability estimate for LSB obtained in this study, 0.15, is in agreement with the findings of Devendra (1984) for Alpine goat in France and Black Bengal goat in India, Hamed *et al.* (2009) for Zaraibi goats in Egypt and Amble *et al.* (1964) for Black Bengal and Beetal goat. Land (1978) reviewed literature on heritability estimates of LSB in sheep and found an average of 0.1. Bradford (1985) 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 to 0.35.

Repeatability estimates obtained for LSB was 0.35. A similar result was found by Odubote (1996) for West African Dwarf goat. This moderate repeatability estimate implies that assessment of prolificacy or culling of unproductive animals based on one individual litter size may not yield the desired accurate results. The repeatability estimate of KI was lower, 0.24, indicating a less predictable estimation of individual KI from single records.

Both genetic and phenotypic correlations between KI and LSB were inferred to be low and slightly positive. A positive correlation could derive from the fact that animals that show larger KI with the previous kidding are expected to show better conditions to carry more fetuses in the following pregnancy. On the other hand, a negative correlation might have been expected since animals that have superior capacities to become pregnant in shorter periods might also be those that can carry more fetuses if the success of the reproductive axis fertility-prolificacy depends on similar pathways in the utilization of energy resources or in the endocrine processes that determine overall reproductive success. The large standard errors associated with the estimated co-variances and subsequent correlations indicate that the amount of available information may not be sufficient to estimate accurately these parameters.

Table 3. Posterior means and posterior standard deviations (in parenthesis) of additive genetic variance (σ^2_a), permanent environmental variance (σ^2_{pe}), residual variance (σ^2_e), heritability (h^2) and repeatability (r), genetic correlation (G_{cor}) and phenotypic correlation (P_{cor}) for reproductive traits.

Variable	σ^2_a	σ^2_{pe}	σ^2_e	h^2	r	G_{cor}	P_{cor}
Kidding interval (months)	5.08 (±4.0)	3.58 (±3.1)	27.00(±3.0)	0.12 (±0.1)	0.24 (±0.1)	0.14 (±0.6)	0.11 (±0.1)
Litter size at birth (kids)	0.039 (±0.02)	0.049 (±0.02)	0.16 (±0.01)	0.15 (±0.08)	0.35 (±0.05)		

Accurate prediction of the breeding values (EBVs) of animals is one of the best tools available to maximize response to a selection plan. The success of a breeding program can be assessed by testing the actual change in breeding value expressed as a proportion of expected theoretical change in the mean of breeding value for the trait under selection.

Fig. 3 shows the trend for the average estimated genetic values per year of birth. As expected from the lack of selection for the reproductive performance, no trend is observed for any of the reproductive traits. This also might indicate that, although harsh, the environmental conditions may be sufficient for a variety of genetic backgrounds to reproduce.

Reproductive performance in this population has remained at a stable level during the past 14 years, showing, however, seasonal variations that point at reduced reproductive results for summer matings. Young females showed somehow worse reproductive performance than older animals, indicating possible conflicts between growth needs and food availability. 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.

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. 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.

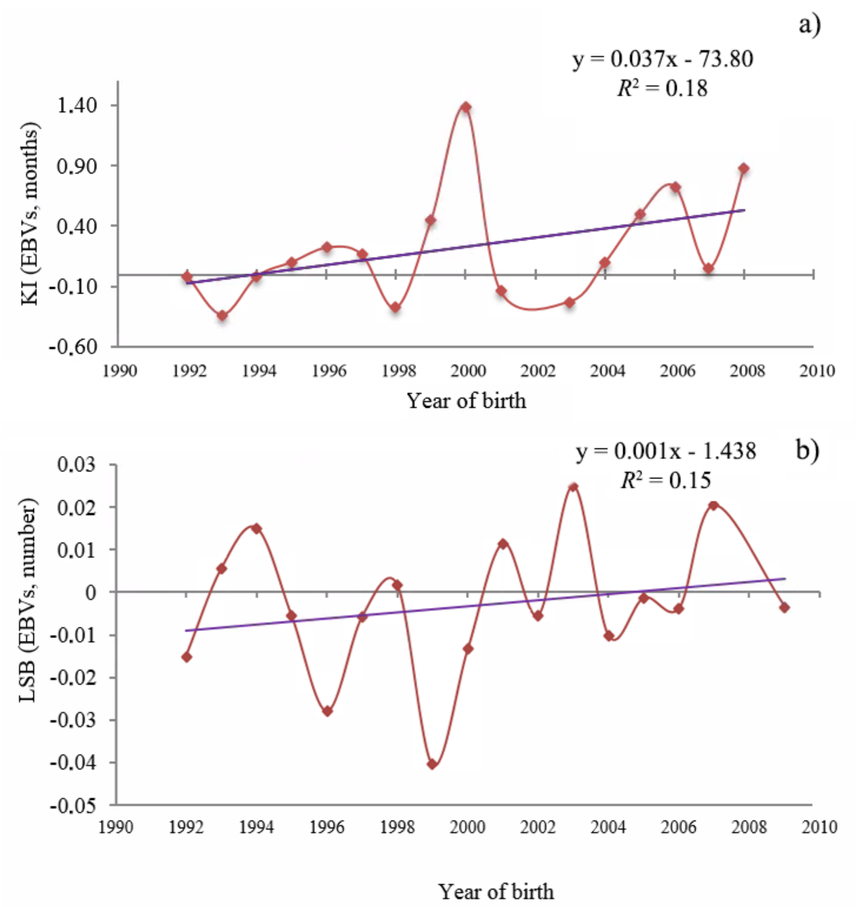

Figure 3. Average estimated breeding values (EBVs) for all animals by year of birth and linear trend adjustment for goat's kidding intervals (KI in a) and litter size at birth (LSB in b).

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