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RESEARCH ARTICLE

ESTIMATION OF GENETIC AND PHENOTYPIC PARAMETERS FOR AGE AT FIRST CALVING AND CALVING INTERVAL IN KURI CATTLE IN NIGER

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ABSTRACT

The aim of the study was to analyse the genetic parameters of age at first calving and calving interval in the Kuri cattle breed, using data from 292 cows from 15 bulls born at the Sayam research station in Niger and monitored over the period 1994 to 2011. Genetic parameters were determined by the mother-daughter regression method and by the variance component method using a father mixed-effects model based on restricted maximum likelihood. The effects of season and year of calving were significant ($p < 0.05$) on the two reproductive parameters studied. Calving interval repeatability, estimated by intraclass correlation, was 0.13 ± 0.05. Heritability's estimated by correlation between paternal half-sisters were 0.14 ± 0.07 and 0.51 ± 0.13 respectively for age at first calving and calving interval. Those estimated by regressing daughters 'performances on dams' performances were 0.25 ± 0.11 and 0.33 ± 0.17 respectively for age at first calving and calving interval. Genetic and phenotypic correlations between the two traits were -0.295 and -0.167 respectively. The high heritability estimates obtained showed a possibility of improving the two reproduction traits through selection.

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INTRODUCTION

The Kuri is a lake breed that has received particular attention in recent decades (Adamou *et al*., 2017; Adamou *et al*., 2018; Adamou *et al*., 2021). In Niger, there have been various reports of threats to animal resources, particularly affecting Kuri cattle (Bourzat *et al*. 1992 and FAO 2004). Cross-breeding to improve other breeds and the destruction of their natural habitats are the most fundamental causes of the threat. It is a bull that nevertheless has interesting qualities in terms of dairy performance and adaptation to the environment (Adamou *et al*., 2021). Kuri farming provides farmers with milk, meat and money, making an essential contribution to livelihoods and household food security. All these aptitudes make this breed a cattle of choice to meet the challenges of livestock production in Niger. Moreover, unlike the Azawak zebu, on which there is a fairly abundant literature (Moussa, 2014), very little work has been devoted to Kuri cattle. Moreover, research on this breed of cattle has remained timid over the last decade. It should also be noted that the breed is tending to disappear even before its characteristics have been studied and its potential assessed. Preliminary characterisation studies are incomplete for estimating the full genetic potential of this population (Adamou *et al*., 2018). With regard to reproductive parameters, observations have focused on the average age at first calving, calving interval, fertility rate and demographic parameters (Adamou *et al*., 2018). Examples include work conducted over several years at the N'Gouri station in the Lake Chad region (Queval *et al*., 1971; Adeniji, 1983), at the Matafo experimental station on the polders of Lake Chad (IEMVT, 1974) and at the Maidougouri breeding centre in Nigeria (Epstein, 1971). These authors reported more or less conflicting results, but ended up considering it as a mixed meat-milk animal. Among traditional pastoralists, milk production has been estimated at between 3 and 6 litres per day (Pagot, 1985). To our knowledge, there are few studies on reproductive performance like Tellah *et al*. (2015). Also, the heritability of these performances has never been published. Knowledge of the genetic parameters of reproduction in cattle plays an important role in assessing the additive genetic value of these traits. The evaluation of additive variance depends mainly on the additive genetic effect of the traits studied, the method and implementation of the model for their evaluation, the sample size and the effect of additivity and the effect of other factors on the expression of production and reproduction. Characteristics (Brzáková *et al*. 2016). Genetic and phenotypic parameters in quantitative genetics play an essential role in the formation of any appropriate breeding design for the breeding programme (Wasike *et al*., 2006; Aynalem, 2006). When estimating genetic parameters, proper identification of sources of variation and their magnitude is also necessary (Siddo *et al*., 2018). The aim of this study was to analyse the genetic factors involved in variations in reproductive performance by assessing the additive genetic value of age at first calving and calving interval.

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MATERIALS AND METHODS

Study area: The study was conducted at the Secondary Livestock Multiplication Center (CSMB) of Sayam located in Diffa (Niger) in the Lake Chad basin area between latitude 13° 84 and longitude 12° 69. The climate is Sahelian in the south and Saharan-Sahelian in the north (CIRAD, 1996). The rainfall regime of the Sayam station is very irregular. From 1997 to 2004, rainfall was very deficient, fluctuating around 200 mm/year. The period from 2005 to 2015 was characterized by the frequency of good rains every two years.

Herd management: The farming method adopted at the Sayam station was extensive. The animals were grazed on perennial herbaceous and annual grass pastures, with internal movements depending on the grazing pattern on the pastures. In the hot dry season (March to early July), the herbaceous pastures deteriorated, and the animals were given a supplement consisting of 2 kg of cotton cake or wheat bran and mineral salt. Water is supplied from two boreholes during the dry season, and from ponds in the rainy season. The animals are herded. Reproduction was carried out by natural breeding, which was sometimes supervised (monitoring of matings). Health monitoring was based on prevention: internal and external deworming, vaccination against PPBC, pasteurellosis and haemato-parasitosis. However, specific treatments against occasional diseases were added to the prophylactic measures.

The data: Reproduction traits were obtained following a retrospective study of cows born at the Sayam station and monitored over the period 1994 to 2008. At Sayam, a brood bull was introduced into each herd of breeding cows, and the observation of mating allowed monitoring of the father-daughter relationship. Individual monitoring consisted of recording the demographic events in the life history of each cow. Based on this information, the reproduction traits were calculated as follows:

- Age at first calving: date of first calving - date of birth of cow;
- Calving interval: difference between the dates of two successive calvings.

Statistical analysis: The data were first subjected to two-factor ANOVA using the GLM procedure in the SPSS 19 program. The fixed factors introduced into the models included the season and year of birth of the cow. For the estimation of genetic components, only cows with known parentage (mother-daughter and father-daughter) were used. Calving interval heritability was estimated using the average of the first three calving intervals, using only cows that had calved at least four times.

Estimation of heritability and repeatability using the variance components method: Variance components were determined by the restricted maximum likelihood method (RELM) according to a father-mixed effect model using the SPSS 19 program, a method used by Boujenane and Mharchi (1992), Djemali *et al*. (1995) and Mouslim *et al*. (1994) to estimate the additive genetic value of zootechnical traits in small ruminants and crossbred calves. In estimating heritability, only cows with known fathers were considered. The file analysed for age at first calving includes the performances of 197 cows from 15 sires with an average of 13 daughters each. The file used for calving interval includes 88 cows from 13 sires with an average of 6 daughters per sire. The mixed model used to estimate the heritability of the two reproduction traits is as follows:

$Y_{ijkl} = \mu + \text{Father } i + \text{Season } j + \text{Year } k + e_{ijkl}$
Y_{ijkl} = performance l of the cow of father i born during season j of year k;
μ = general mean;
Father i = random effect of father i;
Season j = fixed effect of season j of birth;
Year k = fixed effect of year k of birth;
e_{ijkl} = random error relative to the ijkl-th observation.

The levels of the fixed effects introduced into the model are identical for all the two parameters studied:

- three (3) birth seasons: rainy season (July to October), cold dry season (November to February) and hot dry season (March to June);
- year of birth with eleven (11) levels from 1994 to 2011.

Heritability was estimated as 4 times the component of father variance over phenotypic variance: $h2 = \sigma^2_g / \sigma^2_p$ where h2 is heritability, σ^2_g is genotypic variance, and σ^2_p is phenotypic variance.

The standard deviations of the estimated heritabilities were calculated using the approximate formula of Swiger*et al*. (1964):

$SD\ (h^2) = [2(N-1)(1-h)2[1+(k-1)t]2/k2(N-s)(s-1)h]^{1/2}$ where N is the total number of observations, s is the number of groups, $k=[N-(\Sigma n_i2/N)]/(s-1)$; n_i number of observations per group and h the estimated heritability.

Genotypic and phenotypic correlations between age at first calving and calving interval were estimated as the ratio of the covariance between the two traits over the product of their standard deviations. To estimate the repeatability of the calving interval, the variance components were also determined using the restricted maximum likelihood method (Boujenane and Mharchi, 1992). The file used contained 433 performances from 124 cows. The mixed model used and the levels of each of the factors were identical to the model used to estimate heritability, except that the random effect of the sire was replaced by the random effect of the cow. Repeatability was estimated by the following formula: repeatability $r = \boldsymbol{\sigma^2_c}/\boldsymbol{\sigma^2_p}$ where $\boldsymbol{\sigma^2_c}$ is the variance due to the cow effect and $\boldsymbol{\sigma^2_p}$ is the phenotypic variance. Its standard error was estimated using the formula of Swiger *et al* (1964).

Estimation of heritability using the mother-daughter regression method

The estimation of heritability using the mother-daughter regression method was based on 141 and 82 mother-daughter pairs for age at first calving and calving interval respectively. However, the data were previously corrected for non-genetic effects (multiplicative correction). Heritability was estimated as twice the regression coefficient of the daughter's mean performance on the dam's mean performance. Similarly, its standard error was estimated as 2 times that of the regression coefficient.

Calculation of correction coefficients: The correction coefficients of the two factors 'year' and 'season' of birth of the cow were obtained, after analysis of variance of the parameters of reproduction, by the method of least squares. The model used for this purpose is identical to that used for estimating heritability and repeatability. The file used for estimating fixed effects contains 292 data items for age at first calving and 222 data items for calving interval. After estimating the effects of each level of the two factors, a reference class was chosen for each factor, and the multiplicative correction method was used.

RESULTS

Non-genetic factors: The mean age at first calving and calving interval were 46.4 ± 9.1 months and 19.57 ± 6.5 months respectively. The mean calving interval was strongly dependent on the year ($p<0.001$) and season ($p<0.05$) of birth of the cows (Table 1). Similarly, age at first calving depended significantly on the year the cows were born ($p <0.01$, Table 2). However, the effect of season was not significant ($p> 0.05$, Table 2).

Tableau 1. Analysis of variance of mean calving interval

Source of variation	Sum of squares	DF	Mean squares	F
Year of birth	545	13	42	2.2**
Season of birth	144	2	72	3.8*
Year* Season	561	25	22	1.2 NS
Erreur	3267	180	18	

**p<0.01 ; *p<0.05 ; NS no significant difference

The multiplicative adjustment coefficients for the factors of variation with significant effects on each of the variables studied are presented in Table 3. The choice of reference bases was based on the 'rainy season' and 'year 1995' classes for the respective factors of variation season of birth and year of birth. These correction coefficients were used to bring all the performances (calving interval and age at first calving) down to the same level for the year and season of birth of the cows.

Table 2. Analysis of variance of age at first calving

Source of variation	Sum of squares	DF	Mean squares	F
Year of birth	5960.6	13	458.5	7.2***
Season of birth	66.5	2	33.3	0.5 NS
Year* Season	1554.7	26	59.8	0.9 NS
Erreur	17616.0	276	63.8	
***p<0.001 ; NS no significant difference				

The correction coefficients for non-genetic factors indicate that the birth season most favourable to a significant reduction in mean calving interval is the dry and warm seasons. In addition, cows born during the cold dry season and the rainy season were associated with the highest mean calving intervals (Table 3). The correction coefficients show that, compared with the 1995 reference year, age at first calving has improved over the years.

Table 3. Coefficients of correction of non-genetic factors of age at first calving and calving interval

Factors of variation	Calving interval	Age at first calving
Season of birth		
Rainy season	1.00	1.00
Dry season	1.06	1.00
Cold season	0.94	1.00
Birth year		
1994	1.00	1.00
1996	0.92	1.10
1997	0.88	1.12
1998	0.94	1.16
1999	0.95	1.30
2000	0.92	1.28
2001	0.87	1.34
2002	0.99	1.28
2003	1.10	1.27
2004	1.01	1.14
2005	1.06	1.28
2006	1.20	1.05
2007	1.22	1.11
2008	1.07	1.35

Genetic parameters: The heritabilities of age at first calving and calving interval, estimated by the variance component method, were 0.14 ± 0.07 and 0.51 ± 0.13 respectively (Table 4). Heritabilities for age at first calving and calving interval, estimated by the mother-daughter regression method, were 0.25 ± 0.11 and 0.33 ± 0.17 respectively (Table 5). Genotypic and phenotypic correlations between the two traits were -0.295 and -0.167 respectively.

Table 4. Heritability of age at first calving and calving interval estimated by the variance component method

Variance components	Age at 1st calving	Calving interval
Mean ± SD (months)	46,4±9,1	19,4±5,7
Father variance σ2	3,0	3,9
Residual variance σ_e^2	72,5	15,1
Genetic variance σ_g^2	12,1	15,4
Phenotypic variance σ_p^2	84,6	30,5
Number of fathers	15	13
Number of daughters	196	88
heritability h^2	0,14	0,51
Standard deviation of h^2	0,07	0,13

Calving interval decreased with calving order number. The first interval (20.15 ± 6.15 months) was the longest, followed by the second interval (19.73 ± 6.68 months). The shortest was the third interval (18.83 ± 6.84 months). The estimated repeatability of the calving interval was 0.13 with a standard error of 0.05 (Table 6).

Table 5. Heritability of reproductive parameters estimated by the mother-daughter regression method

Traits	Number of couples	Heritability h^2	Standard deviation
Age at 1st calving	141	0.25	0.11
Calving interval	83	0.33	0.17

Table 6. Repeatability of the calving interval of the Kuri cow, estimated by the variance component method

Variance components	Calving-calving interval
Cow variance σ2	4,25
Phenotypic variance σ2 P	32,72
Number of cows	124
Number of performance	434
Repeatability r	0,13
Standard error	0,05

DISCUSSION

Age at first calving and calving interval depended significantly on the year of birth of the cows ($p < 0.01$), whereas season had an effect ($p > 0.05$) only on calving interval. A year of birth with poor feeding and climatic conditions could considerably delay sexual precocity. The Sayam centre has experienced low rainfall and recurrent droughts. Food availability, based essentially on natural pastures, is therefore constantly subject to inter-annual rainfall variability. These factors are compounded by the poor feed value of fodder (Geesing and Djibo, 2001), excessive heat, which clearly reduces potential performance (Meyer, 2009), and climatic hazards, which are all the more pronounced given that the inter-annual variability of rainfall is a determining factor in the variability of available resources in the Diffa region. The coefficient of heritability of age at first calving for the Kuri, estimated by mother-daughter regression, was lower than the values of 0.84 ± 0.09 and 0.26 ± 0.08 reported respectively by Singh et al. (2004) and Dubey and Singh (2005) for some breeds of cattle in temperate countries. For a large number of breeds, studies report low to moderate average heritability coefficients ranging from 0.06 to 0.24 (Vergara et al., 2009; Gutierrez et al., 2002; Solemani-B. et al., 2014; Arough et al., 2011; M'hamdi et al., 2011). Consequently, with an average of 0.25 ± 0.11, Kuri heifers, having calved at an earlier age than the others, could be selected and used to improve this zootechnical parameter. The age at first calving for the Kuri was 46.4 ± 9.1 months. A lower age at first calving is important to increase the number of calves per reproductive career of the cows, which would at the same time lead to an improvement in the frequency of production (milk production for example). The genotypic (-0.25) and phenotypic (-0.17) correlations between age at 1st calving and calving interval, both negative, show that heifers that calved earlier tended to perform better with a shorter average calving interval. Several authors, including Frazier et al (1999) and Haile-Mariam and Kassa-Mersha (1994) were unanimous on the existence of a negative genetic correlation between age at first calving and calving interval.

The low value of the heritability coefficient for age at first calving (0.14), estimated from paternal half-siblings, implies that genetics had little scope for improving this performance, and that non-genetic factors such as herd management practices and environmental factors controlled performance. As a result, we need to make a careful choice of sires to introduce into herds on the basis of their libido and fertility (by examining sperm quality), while ensuring that they are in the best nutritional condition and reforming in good time. The coefficient of heritability of age at first calving varies between breeds, from an average of 0.26 to 0.53 (Goshu et al., 2014; Popescu, 2014). However, as seen in the present study, lower heritability estimates ranging from 0.003 to 0.140 have been obtained in other cattle breeds (Thevamanoharan et al., 2002; Pantelic al., 2011; Lodhi et al., 2016; Seno et al., 2010). Heritability estimates of between 0.33 and 0.51 of calving interval in Kuri populations are higher than the most commonly cited values: 0.03 to 0.07 in holsteins (Pryce et al., 2000; Arough et al., 2011; Solemani-Baghshah et al., 2014; Haile-Mariam and Kassa- Mersha, 1994) and 0.22 ± 0.10 in crossbreds from European breeds (Vinothraj et al., 2016). These variations ranged from 0.11 to 0.29 in zebus and the products of their crosses with temperate breeds (Vergara et al., 2009; Braga Lobo, 1998), and from 0.09 to 0.39 in buffalo (Brzáková et al., 2016; Seno et al., 2010; Roughsedge et al., 2005; Lodhi, 2016; Gutierrez et al., 2002). It is estimated at 0.04 in Boran cattle in tropical environments (Haile-Mariam and Kassa-Mersha, 1994). The variance in these estimates may be due to the use of different statistical models, differences in genetic variation between populations, breeds or varying responses to environmental conditions (Brzáková et al., 2016). Under Kuri breeding conditions in central Sayam, cow calving interval was more influenced by environmental factors ($p < 0.01$). The effect of the year and season of birth of the animals is reflected in an indirect action of the variation in food availability, based essentially on natural pastures that are constantly subject to the inter-annual variability of rainfall. A reduction in the length of the calving interval could therefore be achieved through management interventions such as reproductive management, animal feeding and supplementation practices, and improved animal health. The first calving-to-calving interval is more important, as it is available early in the animal's life for use in any selection programme.

The repeatability of the calving interval is the fraction of the variance of this interval that is attributed to permanent differences between individuals. The higher the repeatability, the more accurate the selection of the best cows based on the first calving interval. In the present study, the calving interval repeatability value of 0.13 was significantly lower than previous studies by Khan et al. (1988) and Vinothraj et al. (2016) in Jersey × Red Sindhi crosses, and that reported by M'hamdi (2011) in Holsteins bred in warm regions. These comparisons suggest that calving interval is influenced by temporary environmental effects. The repeatability of a trait varies with the number of observations, herd, breed and time period (Falconer and Mackay, 1997). In the literature, the repeatabilities of the first calving interval observed in various breeds of cattle reared intensively and relatively uniformly were estimated at 0.06 (Ojango and Pollott, 2001), 0.07 (Haile-Mariam and Kassa-Mersha, 1994) and 0.09 (Oyama et al., 2013). In the present study, the slightly high calving interval repeatability estimate (0.13) may be due to overly extensive exploitation of the Kuri.

CONCLUSION

Environmental factors were a major source of variation in the reproductive performance of the Kuri bull bred at the Toukounous experimental centre. It is therefore important to take these factors into account when estimating genetic parameters and predicting breeding values, in order to avoid bias. Given the importance of the effects of unfavourable environmental factors, this study reports high estimates of the heritability of age at first calving and calving interval in Kuri cattle, showing another possibility for improving these parameters through selection. However, to increase the accuracy of estimating the genetic values of Kuri herds, it will be essential to improve the sample size by strictly controlling the parentage of animals and using a high number of performances for each individual. Performance monitoring must be regular and last over time, including the performances of related animals, in order to have a high number of performances on each individual. The data must be sufficiently documented following a rigorous protocol that would enable the genetic values of the Kuri populations to be estimated in accordance with international standards (Animal Model).

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