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Genetic Parameters and Genetic Trends for Reproductive Traits of Santa Ines Sheep Kept in Extensive Environments in Brazil

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Abstract

Studying the Santa Ines sheep breed is important, as it is the most prevalent breed in Brazil and can adapt to many environments. This study included data were collected over a period of 12 years from 33 flocks in 10 Brazilian States. The estimation of variance components, genetic parameters and breeding values were obtained by DFREML method, using lineal mixed model in single-trait analysis. Traits of age at first lambing (AFL), lambing interval (LI), survivability (SU), litter size at birth (LSB), litter size at weaned (LSW),total litter weight at birth (TLWB) and total litter weight at weaning (TLWW) were assessed. The significance of the fixed effects to be included in the model was performed using statistic program R.

The effects of breeder and lambing year were significant (P<0.001). A remarkable phenotypic and permanent environmental variability were found in all traits. Direct heritability estimates were 0.13, 0.04, 0.01, 0.12, 0.03, 0.16 and 0.18 for AFL, LI, SU, LSB, LSW, TLWB and TLWW, respectively. The estimated fractions of variance due to the permanent environmental effects in any traits were high magnitude (0.79 to 0.97). The annual genetic gain has a slightly negative trend in all of them except for AFL and SU. Results indicate that change in environmental conditions of flock in addition to the direct selection for TLWB and TLWW, can be used as selection criteria for improving the productivity of this sheep.

Keywords: Brazilian sheep; Prolificacy; Heritability; Reproductive efficiency

Introduction

The Santa Ines hair sheep has its origin in the state of Bahia and other states of Brazilian Northeast, from crossbreeding mainly among the breeds Bergamácia, Morada Nova and Somalis. It's known for its hardiness and productivity in the semi-arid environment and therefore, the preferred race of breeders and is probably the most widespread in Brazil [1]. For its pronounced performance in extensive grasslands, the Santa Ines animals are a viable alternative focusing sustainable and environmentally friendly livestock production. The current animal production systems are intensifying livestock, become more sophisticated and seeking increase productivity with better link to animal's genetics, so only the most productive breeds have been selected [2]. This led in last decade the gradual decrease on genetic variability and reduction or disappearance of breeds "less productive" due to the vision of intensification [3].

Livestock production system, whether intensive or extensive, always seek to increase productivity. Thus, reproductive performance and growth rates are among the main responsible indices to maximize profitability [4,5]. An efficient lamb production cannot be performed without controlling reproductive indices such as survivability, age at first lambing, lambing intervals and prolificacy. Therefore, we consider those traits become invariably relevant as selection criteria for animal breeding programs involving sheep breeds.

Numerous studies on the estimation of genetic parameters for "local" breeds of sheep were performed considering reproductive traits related to prolificacy: litter size at birth, litter size at weaned, total litter weight at birth, total litter weight at weaned [6-13]; survivability at weaning age [14,15]; and for the age at first lambing [16].

Studies on genetic effects for productive and reproductive traits in sheep are scarce in tropical areas, like in Brazil, probably due to the lack of genealogical data recording in the flocks. Figueiredo et al. and Ono [17,18], reported estimates for fertility traits in Santa Ines breed, Shiotsuki et al. [19] studied genetic effects involved in lambing interval and total lambs weight at birth and weaned in Morada Nova, another hair sheep breed.

The present study contributes with valuable information for decision making in sheep breeding programs in order to guide the increase of productive and reproductive indices in Santa Ines breed population.

Materials and Methods

Data and management of animals

The information used for these estimates came from the database belonging to Sergipana Association Goat and Sheep Breeders, ASCCO, constituted of 6,566 phenotypic information from 2,211 ewes. These animals were daughters of 377 rams and 1,404 dams. Genealogical structure data of 37,056 animals was used to considerer connections among the population studied. The number of data varied depending on the trait analyzed.

Phenotypic records were collected from 2003 to 2014, coming from 33 herds distributed in 10 different states, more specifically located between latitude 9°S and 26°S; and longitude 40°W and 60°W. The flocks remain in pastures throughout the year.

The native pastures have an important role in their feeding especially for the Northeast region, but other pasture species used are *Brachiaria spp*, *Cynodon spp*, *Cenchrus ciliaris e Panicum maximum*. Besides grazing, animals receive mineral and protein supplementation especially in the dry season. The majority of flocks showed non-controlled reproductive management, maintaining rams and ewes permanently together in pasture throughout the year, Santa Ines sheep do not exhibit seasonal reproductive activity, therefore, births occur through all the year [20].

Table 1 Characteristics of data structure and descriptive statistic for reproductive traits of Santa Ines sheep.

Item	Traitsa						
	AFL (months)	LI (days)	SU (lamb)	LSB (lamb)	LSW (lamb)	TLWB (kg)	TLWW (kg)
Animals in A-1	37,056	37,056	37,056	36,476	36,476	36,476	36,476
N° records	906	2,948	6,558	6,566	4,506	6,566	4,506
N° ewes	906	1,133	2,211	2,211	2,211	2,211	2,211
N° of dams of ewes	703	742	1,403	1,404	1,404	1,404	1,404
N° of sires of ewes	246	215	377	377	377	377	377
Mean	17.4	307.2	1.32	1.3	1.2	4.7	18.1
Standard deviation	2.02	88.2	0.92	0.48	0.4	1.7	8.96
CV (%)	11.6	28.7	69.8	37.3	33.5	36.1	49.6
Range	9.5-20	167-549	0-2	42,826	42,795	1-17.0	5-62.0
Simple birth (%)			69.2				
Duple birth (%)			47.6				
Triple birth (%)			38.4				

[a]AFL: age at first lambing; LI: lambing interval; SU: survivability; LSB: litter size at birth; LSW: litter size at weaned; TLWB: total litter weight at birth; TLWW: total litter weight at weaning

Traits analyzed in the present study were: age at first lambing (AFL), lambing interval (LI), litter size at birth (LSB), litter size at weaned (LSW), total litter weight at birth (TLWB), total litter weight at weaned (TLWW) and survivability (SU).

Variables analyzed for the first six traits were numerical (months, days, number of lambs and kilograms), while SU was a categorical variable, evaluated at weaning, where a ewe with 100% of its lambs alive at weaning time had the value of 2, when 50% of its lambs alive at weaning time had the value of 1 and zero when 0% of lambs were alive at weaning. Outlier records with ± 3 standard desviations from the mean for AFL and LI were excluded. Structural characteristics of the database and the descriptive statistics for the traits studied are showed in **Table 1**.

Methods

First was performed an analysis of variance using the statistical program R (Development Core, 2016) in order to identify the fixed effects to be included in models. The type of lambing (single, double or triple), ewe's year of birth (1992-2011), year of lambing (2003-2014), season (dry or rainy), flock (33 breeders), total lambing of ewe (2 to 10), ewe's age at lambing (from 2 to >0 years: 10 levels) and age lamb at weaning for TLWW (P<0.001), were analysed. Ewe's age at lambing was significant for all traits except for SU, with these exceptions the effects were significant (P<0.001) for most traits under study and hence are included in the models used for each.

Contemporary group (CG) definition varied from trait to trait, including: flock-year-season of ewe birth for LI, flock-year of ewe birth for AFL, flock-year of ewe lambing for LSB, LSW,TLWB and SU, and flock-year-season of ewe lambing for TLWW. In order to obtain a more consistent analysis the CG containing less than three observations and outlier data points were eliminated, thus the CG, lambing year, type of lambing and total lambing of ewe were the fixed effects and as covariates the ewe's age at lambing and lamb's age at weaning (linear and quadratic effect). Direct additive genetic, individual permanent environmental and residual effects as random effects. Analyzes were performed by Restricted Maximum Likelihood method, using single-trait animal models especific for each trait.

Variance components, genetic parameters and breeding values were estimated by DFREML method [21], using MTDFREML software [22]. Convergence criteria was considered when the variance (-2 log L)of the simplex was inferior to 10-9.

The random effect of sire was considered in the analysis of five traits (model 1), while for IPP and IP, model 2 was implemented.

Model 1: $Y = X\beta + Z_a\alpha + Z_s s + W\rho e + \in$ (1)

Model 2: $Y = X\beta + Z_a\alpha + W\rho e + \in$ (2)

Where is the vector of records; **β**, **α**, **s**, **ρe** and **ϵ** are fixed vectors, direct additive genetic effect, uncorrelated sire genetic effect, permanent environment effect on the ewe and residual effect, respectively; with incidence matrices **X,** $\mathbf{Z}_a$, $\mathbf{Z}_s$, and **W** that relate these effects to the records.

Variance components as to phenotypic variance(Q_p^2), being the sum of direct genetic additive variance (Q_a^2) variance due to permanent environmental effect $(Q_{pe}^2)$and residual variance (Q_e^2) were, derived to convergence after they were used to obtain direct additive heritability (h_a^2). The proportion permanent environmental effect of the total variance $(pe^2)$and residual proportion of the total variance, they are the result of dividing (Q_{pe}^2) or (Q_e^2) respectively, for (Q_P^2).

The BLUP procedure was used in order to estimate genetic trends. The annual genetic progress for each trait was estimated as the regression coefficient of ewe's genetic values on their year of birth.

Results and Discussion

Descriptive statistics and fixed effects

Arithmetic means for the evaluated traits in the studied population are presented in **Table 1.** Comparing those performances with the obtained from other Brazilian sheep breeds, observations for LI, AFL and LSB were similar to the ones reported by Quesada et al. [23]. Similar results for LSB were reported by Balieiro et al. [5], Pinheiro [24] in Santa Ines breed, while Oliveira et al. [25] obtained inferior values for LI, analyzing data from only one flock.

Shiotsuki et al. [19] studied Morada Nova breed, reporting inferior mean values of LI when compared to this study, but for TLWB and TLWW, Santa Ines breed seem to have performed better. The percentage of SU from weaned lambs considering its type of lambing (simple, double or triple) were 69.2%, 47.6%, 38.4%, respectively.

All traits were significantly (P<0.001) affected by fixed effects of flock, year-number-type of lambing, excluding the last 3 for AFL. The year of birth of the ewe was significant (P<0.001) both for AFL and LI, while the season effect was significant (P<0.001) for LI and TLWB. All of those significant results can be explained by the existing variation in localization, type of management, feeding and environmental conditions between flocks.

Similarly, annual (and seasonal) differences in pasture conditions, milk availability, ewe's body weight that change with number and type of lambing may also affect the traits analyzed. These significances are according with others studies [8,12,13].

The effect of lamb's age at weaning was significant (P<0.001) for TLWW [7,10,26]. The age of sheep at lambing had a significant effect over all traits studied, except for SU, as observed by Rashidi et al. [7], Masari et al. [9], Nabavi et al. [12] and Mohammadi et al. [11].

In **Table 2** are presented the P-values for the fixed effects, the structure of CG for each trait considered for this study and least square means for distinct ewe's age at lambing.

Variance components and genetic parameters

All traits were analyzed considering that the dependent variable followed a Gaussian distribution. LSB, TLWB and TLWW variables haven't exhibited a Gaussian distribution, however, that assumption was justified for the genetic analysis of those traits in previous studies [4,10,27,28], where not much difference was detected when prediction was performed using linear or non-linear models. In **Table 3** it is shown the variance components estimates, heritability, proportion of the permanent environment and residual effects of phenotypic variance for each trait studied.

In the present study was observed notorious phenotypic and permanent environment variation for all traits analyzed, which consequently affects the magnitude of the additive genetic component. Estimated $h_a^2$of AFL trait was 0.13 ± 0.10, which is in accordance to the findings of Casellas [16] in Ripollese sheep, using Bayesian inference (Piecewise Weibull Proportional Hazards models).

Table 2 Description of fixed effects, least-squares means and standard errors for reproductive traits of Santa Ines sheep.

Fixes effects	Traits						
	AFL	LI	SU	LSB	LSW	TLWB	TLWW
Flock-year birth of ewe-season		***					
Flock-year birth of ewe	***						
Flock-lambing year			***	***	***	***	
Flock-lambing year-season							***
Contemporary groups	105	255	132	118	97	140	178
Lambing year		***					
Type of lambing	NS	***	***		***	***	***
Total lambing of ewe		***	**	***	*	***	***
Dam age at lambing (year)		***	NS	*	*	**	***
2		233^{a} ± 26	1.13 ± 0.06	1.16^{b} ± 0.02	1.22^{a} ± 0.07	4.77^{a} ± 0.25	18.7^{ab} ± 0.36
3		281^{b} ± 7	1.1 ± 0.04	1.19^{ab} ± 0.01	1.21^{a} ± 0.02	4.82^{a} ± 0.07	19.9^{a} ± 0.26
4		337^{c} ± 6	1.1 ± 0.04	1.2^{a} ± 0.01	1.19^{a} ± 0.02	4.79^{a} ± 0.06	19.0^{a} ± 0.28
5		362^{cd} ± 6.5	1.1 ± 0.05	1.21^{a} ± 0.01	1.2^{a} ± 0.02	4.74^{ab} ± 0.06	17.1^{c} ± 0.34
6		402^{de} ± 7.5	1.05 ± 0.05	1.18^{b} ± 0.02	1.17^{b} ± 0.02	4.63^{b} ± 0.07	16.6^{c} ± 0.39
7		410^{de} ± 10	1.0 ± 0.06	1.17^{b} ± 0.02	1.16^{b} ± 0.03	4.52^{c} ± 0.09	15.7^{cd} ± 0.54
8		464^{f} ± 12	1.0 ± 0.08	1.19^{ab} ± 0.03	1.19^{a} ± 0.04	4.45^{c} ± 0.12	15.1^{d} ± 0.74
9		458^{f} ± 18	1.1 ± 0.11	1.14^{c} ± 0.05	1.15^{b} ± 0.05	4.4^{c} ± 0.17	14.1^{e} ± 1.06
10		404^{ef} ± 27	1.15 ± 0.14	1.16^{b} ± 0.07	1.04^{c} ± 0.08	4.15^{d} ± 0.26	15.3^{d} ± 1.6
>10		463^{f} ± 23	1.22 ± 0.13	1.16^{b} ± 0.05	1.22^{a} ± 0.06	4.5^{c} ± 0.22	13.6^{e} ± 1.03
Age lamb at weaning							
NS (not significative); *(P<0.05); **(P<0.01); ***(P<0.001)							

Table 3 Estimates of variance components and genetic parameters for reproductive traits of Santa Ines sheep.

Parametersb	Traitsa						
	AFL	LI	SU	LSB	LSW	TLWB	TLWW
	391.55	230.46	0.00675	0.02669	0.00143	0.1299	6.2
	2,407.40	5,627.10	0.5011	0.1859	0.0514	0.6436	26.397
	208.02	500.2	0.00715	0.0045	0.00317	0.0417	0.993
	3,006.97	6,357.76	0.515	0.2171	0.056	0.8152	33.59
	0.13 ± 0.10	0.04 ± 0.017	0.01 ± 0.012	0.12 ± 0.014	0.03 ± 0.014	0.16 ± 0.0147	0.18 ± 0.021
	0.80 ± 0.10	0.88 ± 0.017	0.97 ± 0.010	0.86 ± 0.015	0.92 ± 0.014	0.79 ± 0.0169	0.79 ± 0.02
	0.069	0.078	0.014	0.02	0.056	0.05	0.03

[a] For trait abbreviation see footnote of **Table 1**.

aaa=additive genetic variance; aaa =permanent environmental variance; aaa =residual variance; aaa =phenotypic variance; h^2=heritability;

pe^2= aaaaa =permanent environmental proportion of phenotypic variance; e^2 = aaaaa =residual proportion of phenotypic variance.

Also, in a study by Ono [18], considering data from the same population studied in this research, but without including a permanent environment effect, obtained a moderate heritability (0.24 ± 0.05), also by a Bayesian approach.

The estimated h_a^2 for LI was 0.04 ± 0.017, similar to the results in Ono [18]. Lower values were obtained by Zishiri et al. [15] in Dorper sheep (0.01) and by Shiotsuki et al. [19] for Morada Nova breed (0.0), demonstrating that this trait has much more influence from environmental effects (pe2=0.88), than additive genetic effects. Heritability for SU from weaned lambs, which is evaluated in the ewe and represents its capacity to maintain its progeny alive from birth to weaning, was of low magnitude (0.01 ± 0.01), also similar to results obtained by Ono [18] and other authors [14,15].

The low genetic variability found for this trait takes to the understanding that to improve it, environmental factors are of much more importance than genetic ones [29]. Nevertheless, Cloete et al. [30] reported that previous studies suggest the existence of families inside the population showing higher survival ability, therefore, must be considered as a selection criterion both in ewe and lamb levels.

Rashidi et al. and Mohammadi et al. agree that the inclusion of a random sire effect for traits related to prolificacy had no significant values [7,11]. The number of lambs at birth (LSB) had a h_a^2 of 0.12 ± 0.014, which is similar to results obtained by other authors [6-8,18,28], but considered high when compared to the findings of Ceyhan et al., Mokhatari et al., Masari et al., Mohammadi et al., Zishiri et al. and Nabavi et al. which reported values from 0.01 to 0.079. However, we have identified studies where estimated heritability was high as in Mohammadi et al., Yavarifard et al. [11,13] that observed values of 0.17 and 0.16, respectively.

All these results confirm that LSB trait must be considered as a selection criterion for Santa Ines breed.

Estimated h_a^2 for LSW presented value of 0.03 ± 0.014, in accordance to results obtained by other authors but low when compared to studies reported by Hanford et al., Ceyhan et al., Boujenane et al., Nabavi et al., Mohammadi et al. and Yavarifard et al. [6,8,11-14], who found values between 0.07 and 0.21. LSW showed strong permanent environmental effect (pe2=0.97).

Thus, by improving post-lambing environmental conditions, the ewes can show its maternal ability allowing a more accurate selection process for this trait. Also, a positive genetic correlation with SU (0.82 ± 0.26) was reported for Ono (2015) on the same population studied in the present study.

Total litter weight at birth (TLWB) measures the ability of the ewe to produce heavy lambs at birth without disregarding the number of lambs, had h_a^2 value of 0.16 ± 0.014. Studies performed in other population showed similar results [9,12,28]. Shiotsuki et al. [19] reported heritability of 0.44 ± 0.12 in the Morada Nova breed.

However, low estimates (between 0.0 and 0.10) were reported by Mokhmtari et al., Rashidi et al., Boujenane et al., Mohammadi et al., Onoand Yavarifard et al. [7,8,10,11,13,18,26] The high heritability value of this specific trait when compared to other populations and its high genetic correlation with reproductive traits, especially TLWW [7,9-12], indicate the possibility to improve reproductive and productive efficiency while reducing generational intervals and incrementing genetic trends [12,26].

According to Mohammadi et al. and Yavarifard et al. [10,13], TLWW trait has economic importance and reflects the maternal and reproductive ability of ewe, as well as the survivability and growing of lambs during the pre-weaning period.

In the present study, obtained h_a^2 was high (0.18 ± 0.021) when compared to the estimated by other authors [7-11,18,26] and similar to the obtained by Mokhtari et al. [26], Nabavi et al. [12], Shiotsuki et al. [19] and Yavarifard et al. [13]. This high heritability indicates that selection based in TLWW trait may generate good results for reproductive and productive efficiency in this population. Also, TLWW has positive genetic correlation with other reproductive traits as reported by many authors.

The proportion of the permanent environment (pe^2) of total phenotypic variance was of high magnitude for all traits studied (0.79 to 0.97), which is much higher than the heritability estimates for the same traits. This result probably happened due to the fact that data came from extensive livestock production system based on pasture during all year (where there are heterogeneous animal management programs coming from different flocks), associated to the high environmental pressure suffered by animals due to the intense climate in tropical regions.

It gets clear the importance of considering the permanent environment effects when analyzing data from extensive livestock production systems. Studies considering highly controlled environmental conditions [7-13,26,28], showed much lower estimates (0.23 to 0.0) when compared to our results.

Estimated genetic trends

It has been evaluated the annual genetic change in each of the reproductive traits considered in the present study during the period of 24 years (1990-2014) and are presented in **Figure 1**.

Means of the estimated breeding values (BV) for the traits related to prolificacy (LSB, LSW, TLWB and TLWW) show a slightly negative trend, demonstrating that those traits not had been take into consideration in the selection process by breeders. The LI trait presents a positive trend (0.05 days/year), denoting an increase in the lambing interval of the population although in a low magnitude. Therefore, environmental changes would allow an accurate selection process in this population.

In a different fashion, AFL trait showed a slight favorable trend (-0.012 days/year). The SU trait also shows a slight positive trend, but by having a very low additive genetic component, indicates that changes in performance must probably be by environmental condition improvement in the post weaning period.

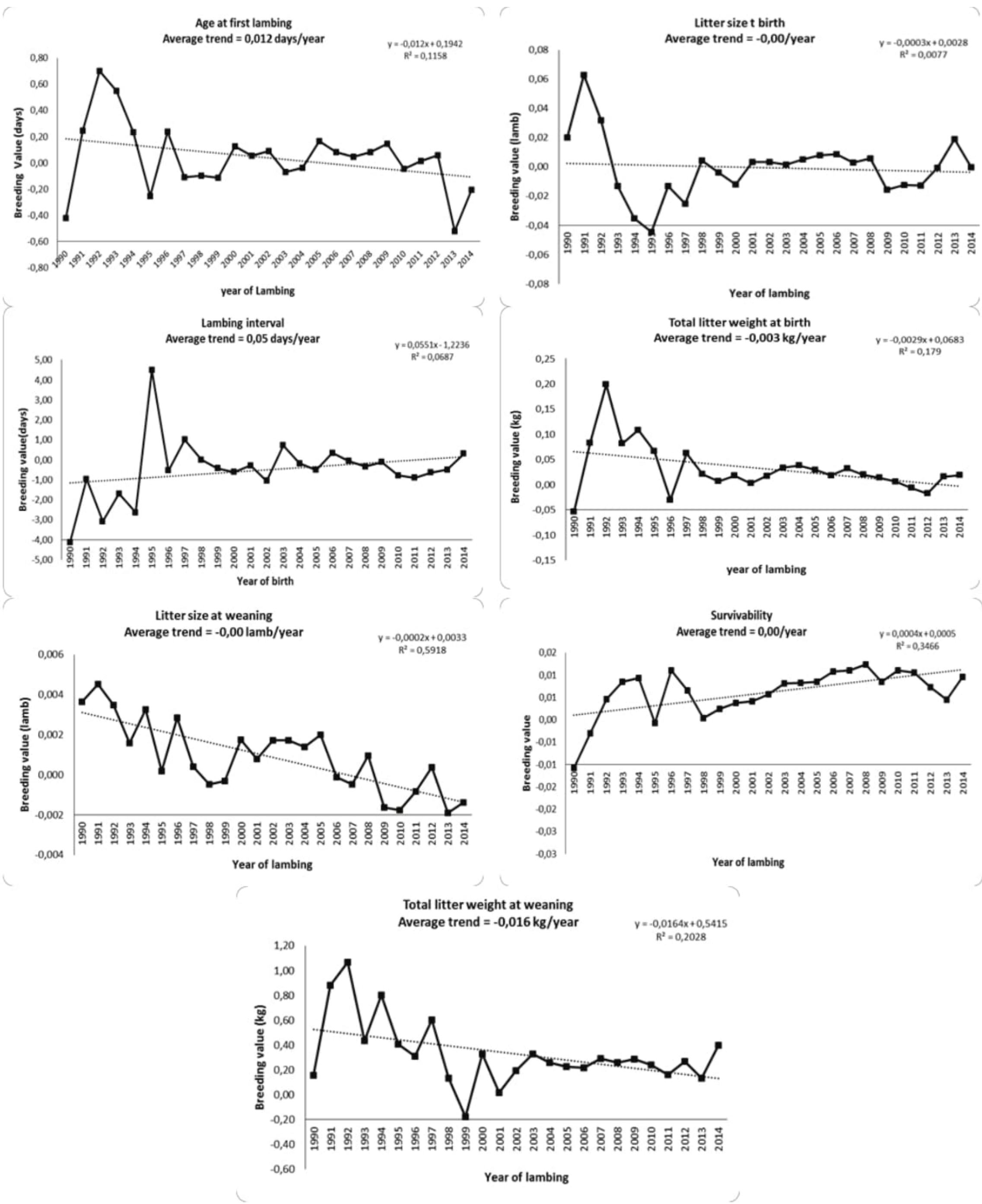

Figure 1 Genetic trends for AFL, LI, SU, LSB, LSW, TLWB and TLWW for the Santa Ines population studied.

Conclusion

The present study shows that Santa Ines sheep breed, when under extensive livestock production systems, exhibit high permanent environment effects for the traits analyzed. Also, moderate heritability was shown for traits related to prolificacy and age at first lambing, while low heritability was reported for lambing interval, survivability and the number of lambs at weaning. This indicates that selection based on ewe performance will provide only slow genetic improvement. It is suggested than, that changes on environmental conditions of the flock, as well as selection for PTCP and PTCD traits (which are positively correlated to other reproductive traits), evaluated at the first lambing, may be used as selection criterion for the decrease of the generational interval, improving productivity and genetic trends of the studied population.

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Conflict of Interest

The authors declare that they have no conflict of interests and the manuscript is their original research.

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