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Effects of service ram on litter size in Romanov sheep

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ABSTRACT

The objective of the present study was to examine and quantify the effects of factors acting during the mating period (service ram, mating group) on subsequent litter size in the highly prolific Romanov breed of sheep and to propose models for the potential inclusion of this effect in mixed model equations for breeding value estimation. A dataset of 4412 lambings of purebred Romanov sheep in a performance test program from 1998 to 2013 was used in analyses. The basic model fitted to litter size was a single-trait repeatability animal model with fixed effect of ewe age and random effects of contemporary groups of ewes during lambing, direct additive genetic effect of ewe, permanent environmental effect of ewe and random residual. Eight modifications of the basic model examined various combinations of mating effects, contemporary group of ewes during mating (harem), and additive genetic and permanent environmental effect of service ram. When the service ram effect was analyzed without inclusion of the population relationship matrix in the model, the proportion of variance attributable to service ram was 0.081. When the relationship matrix was included in the analysis, however, service ram heritability estimates varied from 0.046 to 0.10, depending upon whether ramís permanent environmental effect, a harem effect or both were included in model. Models containing the additive genetic effect of service ram had slightly lower proportions of residual variance than models lacking this effect. Including effects of mating (service sire, harem, and/or ramís permanent environmental effect) in the model favourably decreased deviance information criterion. Means of estimated BVs by year of birth increased across the 22 years from about 0.45–0.60 lambs per litter for female fertility and from 0.55 to 0.59 lambs per litter for BV male contribution on litter size, with only small differences among models. Results from present study demonstrate that service rams in Romanov sheep have a clearly detectable influence on litter size of their mates. Genetic parameter estimates indicate that direct selection on the service ram effect could increase litter size and achieve genetic gain through ram selection.

1. Introduction

Reproductive traits including litter size are critical factors for efficient sheep production. Selection for litter size is included in the vast number of breeding programs for sheep. However, selection response for this trait usually is not substantial, partially because heritabilities for the trait of approximately 0.10 allow selection response only up to 2%/year from simple mass selection (Notter, 2008). For reliable estimation of breeding values for litter size, it is important to consider all relevant systematic factors influencing the trait. Traditionally, litter size is considered and evaluated as a trait of ewe. However, prolificacy is a complex trait (Fig. 1) and, as described by Hamann et al. (2004) in pigs and Shorten et al. (2013) in sheep, it can also be influenced by paternal and fetal effects.

Service sires can influence both fertilization and prenatal survival rate. Such effects can be due to mating behavior (Perkins et al., 1992), social relationships among animals (Rosa and Bryant, 2002), genetically determined variation in fertilizing capacity (sperm quality) and the genetic contribution of the sire to viability of the embryo (van der Lende et al., 1999). Serious fertility problems can arise if rams suffer from handicaps in locomotion or other health problems, e.g. foot rot during the time of mating (Hagger, 2002; Shorten et al., 2013). Appropriate timing of mating in relation to sperm transport and ovulation time is essential for conception and also for litter size in the case of multiple ovulations (Schott and Phillips, 1941). Thus more sexually active rams with good quality semen have a higher chance to fertilize all ovulated ova. Some covariation between male and female fertility components can be

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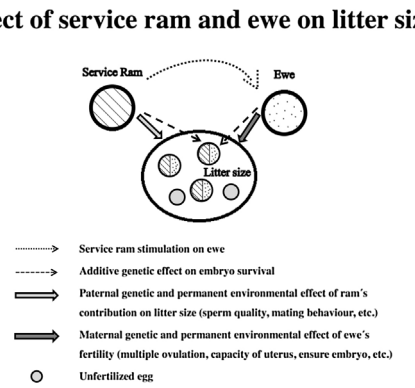

Fig. 1. Effect of service ram and ewe on litter size.

expected, and some genetic correlations among male anatomical traits and female reproductive traits have been described. For example, Coulter and Foote (1979) and Hanrahan and Quirke (1988) reported that scrotal size of the sire was correlated with ovulation rate, fecundity, and age at puberty of daughters in both cattle and sheep. Al-Shorepy and Notter (1996) reported that the genetic correlation between scrotal circumference of 90 day old rams and litter size of daughters was 0.36.

Hagger (2002) and Sánchez-Dávila et al. (2015) described genetic evaluations for number of lambs born per ewe using model equations that included a service ram effect. Schmidova et al. (2015) presented preliminary analyses on the evaluation of service ram effect on litter size in sheep incorporating information from the population genetic relationship matrix showed Schmidova et al. (2015). Another factor that is generally not taken into account in breeding values estimation is mating groups of ewes (the harem). Contemporary group generally is considered that group of ewes lambing in the same flock during the same period of time, which may or may not correspond with the mating group. In addition to the ram effect on conception of ewes for a current mating season, their subsequent prolificacy can be influenced by environmental factors acting on the mating group. In view of the foregoing, the objective of the present study was to examine and quantify the effects of the factors acting during the mating period (service ram, mating group) on subsequent litter size in the highly prolific Romanov breed of sheep and to propose models for the potential inclusion of this effect in mixed model equations for estimation of genetic parameters and breeding values.

2. Material and methods

2.1. Data

Data from Romanov ewes performance test from 1998 to 2013 were provided by the Sheep and Goat Breeders Association of the Czech Republic. The database contained information on animal (lambing ewe), flock, date of lambing, ewe age at lambing, parity, interval between successive lambings, service ram and litter size. Four generations of known ancestors were added from the pedigree database. Litter size was recorded on the day of lambing as total number of lambs born. Only natural matings were included. Records were deleted from the database prior to analysis for crossbred ewes, ewes with an unknown age (unknown date of birth), ewes lambing at younger than 10 months or older than 140 months of age, ewes whose sire had fewer than 4 daughters with at least two lambing records each, flocks where only one ram was used, and rams used in only one flock-year subclass. Contemporary groups (CG) were created of ewes that lambed within successive 40-day intervals in the same flock and year (Schmidova et al., 2014). Those CG's with fewer than 7 ewes were excluded from analyses. Another contemporary group category identified as

Table 1
Distribution of the number of lambs per litter class and overall descriptive statistics.

Litter size	1	2	3	4	5	6	Total	Mean	SD
N	491	1583	1673	576	79	10	4412	2.59	0.93
%	11.13	35.88	37.92	13.06	1.79	0.23			

Explanations: N: number of lambings with 1–6 lambs in litter; %: percentage of lambings with 1–6 lambs in litter.

Table 2
Number of lambings (N), average (LSM) and standard error (SE) for litter size in different age and parity classes of ewes.

Age in months	10–18	19–30 (1.parity)	19–30 (2.parity)	31–42	43–78	79–102	103–150
n	666	408	400	1079	1530	272	57
LSM	2.11	2.36	2.48	2.65	2.79	2.64	2.33
SE	0.05	0.04	0.04	0.03	0.02	0.06	0.12

Table 3
Effects in the models.

	Age	CG	Ewe	Ewpe	S. ram	Spe	Harem
Model B	x	*	*	*			
Model H	x	*	*	*			*
Model R	x	*	*	*	*		
Model SG	x	*	*	*	RM		
Model SP	x	*	*	*	RM	*	
Model SH	x	*	*	*	RM		*
Model SPH	x	*	*	*	RM	*	*
Model SG-C	x	*	*	*	RM-C		
Model SP-C	x	*	*	*	RM-C	*	

Explanations: Age is the age class of ewe at lambing; CG is the effect of contemporary group of ewes lambed during a 40 day interval; Ewe is the direct additive genetic effect of ewe; Ewpe is the permanent environmental effect of ewe; S. ram is the effect of service ram; Spe is the permanent environmental effect of service ram; Harem is the effect of contemporary group of ewes mated with one ram during one year.
x—fixed effect; *—random effect; RM—joint relationship matrix for additive genetic effect of ewe and service ram effect; RM-C—joint relationship matrix for additive genetic effect of ewe and service ram effect with genetic correlations.