

The relationship between the reproductiveness of ewes and testicle size of related rams

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(Received 28 September 1993; accepted 12 May 1994)

ABSTRACT

The experiment was conducted on 395 ewes and their 585 half-brothers divided into groups according to sires (50 and 37 groups, respectively). The date of the first oestrus in yearling ewes, date of successful mating of older ewes and the number of lambs born were studied.

Testicular diameter and scrotum circumference were measured in growing rams during stimulatory and inhibitory photoperiods. The results of testicular measurements of these young rams were compared with the corresponding periods of sexual activity and reproductivity of related ewes. It was found that the sire's genotype affected the timing of sexual activity of ewes during the spring-summer breeding season. The date of successful mating of yearling ewes was highly correlated ($P \leq 0.01$) with their body mass. The correlation between the testis diameter index of rams at 28 days of age and the period of the first oestrus in yearling ewes was significant ($P \leq 0.05$; $r = 0.35$), while that between this index and the date of successful mating during the first breeding season was highly significant ($P \leq 0.01$; $r = 0.37$). Significant correlations were also found between the scrotum circumference index at 100 days of age and the period when fertilization of ewes occurred during the first breeding season ($r = 0.28$) and between this index and the number of lambs born in the first lambing ($r = -0.27$).

KEY WORDS: sheep, first oestrus, breeding activity, breeding performance, size of testicles

INTRODUCTION

The gonadotrophic hormones, FSH and LH, take part in regulating both spermatogenesis and the development of ovarian follicles and ovulation, thus forming the basis for a correlation between male and female fertility (Land,

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1974). Studies on cattle and pigs have demonstrated a significant genetic correlation between testicular size in males and age at puberty of their daughters (King et al., 1983; Land, 1974) and fertility of their sisters (Owsiany et al., 1991).

Sheep have a seasonal breeding period resulting from the sensitivity of their endocrine system = genotype, to changes in the photoperiod (Ortavant, 1977). This is manifested in males by an increase in testicular size, mass and volume during longer photoperiods (Doufour et al., 1984). Ringwall et al. (1985) found that changes in testicle size were correlated with changes in ovary function of related females. This would suggest that it is possible to select for longer breeding periods in ewes by choosing rams with the least fluctuating testicle size.

The objective of this study was to evaluate the reproductivity of ewes and testicular size of their half brothers.

MATERIAL AND METHODS

The study was carried out in a farm on Polish Merino sheep. The studied group encompassed 395 young ewes the offspring of 50 sires, and their 585 half-brothers.

The prolificacy of the ewes was determined independently in each of their first three breeding seasons (Rep 1, Rep 2, Rep 3) and jointly in the first two (Rep 1 + Rep 2). The third season was not taken into jointly account because of a large decrease in the number of ewes. The mating activity of the ewes was determined according to the date of the first oestrus (in yearling ewes) or date of mating (in older ewes). Ovulation in yearling ewes (AKT 0) was determined directly by releasing a test ram twice daily to identify females in heat. The date of mating during the first (AKT 1), second (AKT 2) and third (AKT 3) reproductive season was determined directly during controlled breeding or indirectly during random breeding by subtracting the mean duration of pregnancy (151 days in the Polish Merino) from the date of lambing. All three breeding seasons were begun between May 1 and 3, i.e. one month earlier than recommended for this breed. The timing of oestrus in ewes was assessed from the point of view of possible extension of reproductive period. For this purpose the breeding season was divided into three periods according to which the manifested activity was classified. The first period comprised the first 17 days of the breeding season (counting from the first contact of the ewe with a ram). Ewes characterized by a long oestral period can develop oestrus spontaneously during this period, i.e., without additional stimulation. During the second period, between days 17 and 25, oestrus appears naturally or, in most ewes, as the result of earlier contact with a ram – the so-called "ram effect" (Nowakowski, 1987). The third period encompassed the successive 17 days, in other words, the average duration of the sexual cycle in sheep. Ewes characterized by a later reproductive season come

into oestrus spontaneously at this time or, sporadically, as a delayed "ram effect". A fourth period was set apart for those ewes that had a later or shorter oestral period and did begin oestrus until after the planned 6-week breeding season. The ewes sexually active during the first three periods were supervised mated (2 controlled ejaculations per ewe in heat), those active in the fourth bred without man control.

The reproductivity of ewes was assessed in paternal groups using least squares variance analysis according to Harvey (1987) and a set model:

$$Y_{ijk} = u + a_i + b_j + c_k + e_{ijk}$$

where:

Y_{ijk} - AKT0, AKT1, AKT2, REP 1, REP 2, REP 1+2

u - mean for studied population

a_i - effect of sire's genotype ($i = 1 \dots 50$)

b_j - effect of ewe's birth-type ($j = 1, 2$)

c_k - effect of yearling ewe body mass ($k = 1 \dots 3$)

e_{ijk} - error.

Birth-type is understood to mean the type of pregnancy from which the ewe was born: 1-single or 2-twin; yearling ewe body mass: 1-lower (45-52 kg), 2-medium (52-59 kg), 3-higher (59-66 kg). The effect of body mass was taken into account for all of the seasons. Variance analysis within each of the years was carried out in a orthogonal system, while for the factors over all three seasons in a non-orthogonal system on individual data for each season.

Concomitantly with the ewes, their half-brothers were also assessed, but in just 37 paternal groups since only those groups numbering more than 3 daughters and 5 sons were taken into consideration. Only those individuals with healthy and symmetric testes were included in the study. Gonad size and body mass were determined at the ages of 28, 100 and 150 days.

The diameter of the left testis in its widest part was measured with an accuracy of ± 0.5 mm on the 28th day of life, subtracting the scrotum skin-fold thickness. The scrotum circumference was measured with an accuracy of ± 0.5 cm on days 100 and 150 of life. Concomitantly with testicular measurement, the rams were weighed with an accuracy of ± 0.1 kg. These measurements were then used to calculate indexes characterizing growth and testicular development in relation to overall development (Schoeman and Combrink, 1987). The IS 28 index is the ratio of testicle diameter to body mass of rams at 28 days of age, while the IO 100 and IO 150 indexes, the ratio of scrotum circumference to body mass at ages 100 and 150 days, respectively.

Rams were compared in paternal groups by using the indexes according to the following model:

$$Y_{ij} = u + a_i + b_j + e_{ij}$$

where:

Y_{ij} – indexes: IS 28, IO 100 IO 150

u – mean for studied population

a_i – effect of sire's genotype ($i = 1 \dots 37$)

b_j – effect of type of birth and rearing ($j = 1, 2$)

e_{ij} – error.

Because most of the rams born as twins were also reared as twins (98%), birth type was also equivalent to rearing type in the statistical calculations.

This type of analysis was used to rank the rams in paternal groups in agreement with the paternal groups of the evaluated half-sisters, making it possible to compare testicular measurements with the periods of sexual and reproductive activity of related ewes during the first two years of the study.

The relationships between the traits in paternal groups were studied by calculating the phenotype correlation coefficients and linear regression equation using the statistical program SPSS/PC (Niemic, 1990).

RESULTS AND DISCUSSION

Mean prolificacy, mean periods of manifestation of sexual activity of ewes (expressed according to the periods into which the breeding seasons were divided) and a comparison of the range of these means for paternal groups of ewes are presented in Tables 1 and 2. The lower mean prolificacy of ewes (Table 1) in the first breeding season can be related to the early mating season (May), since the sexual activity of yearling ewes is lower and occurs during the peak activity of older ewes (Bielański, 1977). The distribution of sexual activity of

TABLE 1
Reproduction data on the studied ewes (37 paternal groups)

Trait	Number of ewes	Prolificacy	SE	Max.– min. prolificacy of paternal groups
REP 1	320	0.999	0.013	0.67 – 1.44
REP 2	220	1.43	0.017	1.00 – 2.00
REP 1+2	220	2.43	0.019	1.79 – 2.97

REP 1 – number of lambs born to a ewe at first lambing

REP 2 – number of lambs born to a ewe at second lambing

REP 1+2 – total number of lambs born to a ewe in first two lambings

TABLE 2

Data on sexual activity of ewes (from 50 sires) during 3 successive breeding seasons

Train	Number of ewes	Time from the start of breeding season mean (days)	Period of activity*		Max - min activity of paternal groups (periods)
			mean	SE	
AKT 0	392	35	2.47	0.052	1.25 - 3.50
AKT 1	392	40	2.81	0.056	1.50 - 4.00
AKT 2	291	37	2.63	0.054	2.00 - 3.75
AKT 3	87	40	2.81	0.091	1.00 - 4.00

* see Methods

AKT 0 - date of first oestrus

AKT 1 - date of mating during first breeding season

AKT 2 - date of mating during second breeding season

AKT 3 - date of mating during third breeding season

TABLE 3

The number of active ewes during the particular breeding seasons and their periods

Period of activity	Season		
	first	second	third
1	71	30	5
2	151	104	26
3	77	99	37
4	87	58	19
Total	392	291	87

ewes during the particular periods of the first three breeding seasons is given in Table 3.

A highly significant correlation ($r = 0.73$) between the period when sexual maturity was reached (AKT 0) and the period when fertilization occurred (AKT 1) was found in the first breeding season, which results from the fact that most of the ewes were fertilized during their first oestrus.

The effects of sire's genotype, type of birth and body mass on the period when sexual activity was demonstrated during the first breeding season (AKT 1) are given in Table 4. The date of the first oestrus is related mainly to body mass (Table 4), in agreement with Tierny's (1976) earlier findings. The greater the body mass of the ewes, the earlier they began to demonstrate sexual activity. Ewes weighing on average 50 and 60 kg came into oestrus during the third and second periods of activity, respectively. The mean mass of yearling ewes during their first oestrus was 55.7 kg. The sire's genotype, type of birth and the ewe's body mass before the first breeding season were found not to have any effect on the period

TABLE 4

The effect of sire's genotype, type of birth and body mass of ewes on the period of manifesting sexual activity (oestrus) during spring/summer breeding seasons

Source of variability	Degrees of freedom	In one reproductive season ¹			In three reproductive seasons ²		
		sum of squares	P	% of variability	sum of squares	P	% of variability
Paternal group	49	118.68	0.16	14.54	78.40	0.03	17.00
Type of birth	1	0.04	0.88	0.01	0.15	0.71	0.03
Body mass	2	17.08	0.01	2.09	3.42	0.21	0.74
Error	342	680.34	-	83.36	379.17	-	82.23
Total		816.14		100.00	461.14		100.00

¹ Variance analysis in an orthogonal system

² Variance analysis in a nonorthogonal system

when fertilization occurred during the second breeding season. However, the sire's genotype was found to have a significant effect on the mean period of fertilization over all of the breeding seasons (Table 4). During the first breeding season, the effect of the sire's genotype on the period during which mating was effective was only close to the level of significance. This could be caused by the fact that hormonal regulation in yearling ewes is more dependent on the photoperiod than in older ewes; this was found by, among others, Korman (1986). Analysis of the results presented in Table 4 shows a distinct trend towards the effect of the sire's genotype on the period of manifesting sexual activity by ewes during spring-summer breeding seasons. These results support those obtained by Land and Lee (1976), who showed that the start of the reproductive period was much earlier in 18-month-old females from lines in which the males had been selected for fast testicular growth than in lines where such selection had not been made. Veress and Kakuk (1983) found by studying the ovaries of slaughtered Merino ewes that their activity does not totally subside during the oestrus-free period or, if it does, then only for a much shorter time than external symptoms seem to indicate. Ovulation without signs of oestrus, i.e. silent oestrus, causes the sexual cycle to shorten or lengthen, but does not affect the fertility of the female. This is proven by the possibility of extending the breeding season of females by appropriate selection for this trait.

Table 5 gives the mean testis dimensions of the studied rams. According to the studies of Toella and Robinson (1985) mean values are more highly correlated with reproductive traits than are individual measurements made at a given age. Table 5 also gives the testimetric traits in the form of indices that eliminate the effect of different growth when comparing testis development in paternal groups of rams (Schoeman and Combrink 1987). The effect of the sire's genotype on the

TABLE 5

Characteristics of the ram-lambs

Age (days)	Body mass (kg)	Testis diameter ¹ (mm)	Scrotum circumference ² (mm)	Index \pm SE
28	9.2	5.9	—	0.637 \pm 0.005
100	26.6	16.1	126.9	0.477 \pm 0.002
150	38.1	30.6	195.8	0.514 \pm 0.003

¹ Testis diameter index at age 28 days (IS 28) = testis diameter/body mass

² Scrotum circumference index at age 100 days (IO 100) = Scrotum circumference/body mass

² Scrotum circumference index at age 150 days (IO 150) = Scrotum circumference/body mass

testimetric traits of the sons was found by, among others, McNeilly et al. (1986), while Yarney et al. (1990) found a correlation between testis size in younger and older animals.

Day 28 of life when the measurements were made occurred during the stimulatory phase of the photoperiod (November), while the measurements on days 100 and 150, when it was inhibitory for reproductive functions of sheep (January and March, respectively). This made it possible to determine the variation in testis size depending on changes in the photoperiod.

The phenotypic correlation between the testis diameter index of half-brothers at 28 days (IS 28) and age at puberty of ewes (AKT 0) was significant ($r = 0.35$), while the correlation between this index and the period when fertilization took place during the first breeding season (AKT 1) was highly significant ($r = 0.37$). The regression equations for these traits show that increased testis diameter at 28 days (x , mm) delayed the first oestrus (Y_1) and the period when fertilization occurred during the first breeding season (Y_2):

$$Y_1 = 5.047x - 0.800 \quad R^2 = 0.35 \quad P = 0.03$$

$$Y_2 = 5.132x - 0.399 \quad R^2 = 0.37 \quad P = 0.02$$

Testicular diameter on day 28 was measured when the photoperiod was stimulatory for testis development. This justifies the supposition that those rams with high values of this index (IS 28) will be sensitive to changes in the photoperiod and that the ewes related to them will have a breeding period strictly determined by the photoperiod which is in agreement with the results of the studies by Walton et al. and Lincoln and Davidson (according to Webster and Barrell, 1985) and Ortavant (1977).

Fraser and Laing (1969) and Hafez (1952) according to Orvant (1977) found it possible to experimentally provoke oestrus in ewes and increase testicle volume in rams by decreasing daylight. This, however, must be preceded by an

appropriate period of incubation. Dufour et al. (1984) showed that changes in testicle volume are a good indicator of the susceptibility of the endocrine system and, indirectly, of the genotype, to changes in the photoperiod. This study has also shown that there is a significant positive correlation between the scrotum circumference index at age 100 days (IO 100) and the period when fertilization during the first breeding season (AKT 1) occurred ($r=0.28$) and a significant negative correlation between this index (IO 100) and the number of lambs born during the first breeding season (REP 1; $r = -0.27$). Testis circumference was measured at age 100 days in January when the duration of daylight was inhibitory. This measurement was made, then, only one month after the winter solstice (December 22), thus, during the period of incubation which, according to Hafez (1952, cit. Ortavant, 1977) equals 10-25 weeks. It should thus be supposed that the rams with a high index (IO 100) and their related ewes will be characterized by a reproductive season determined by changes in the photoperiod. Conversely, those ewes whose brothers had low values of this index should be expected to show early sexual activity and, it can be supposed, the activity of their ovaries will be cyclical year round. The genetic correlations between testicle size of young rams and the level of ovulation were shown in the studies of Schoeman et al. (1987) and Purvis et al. (1988).

In the current study we found that the increase in testicular circumference on the hundredth day of life, IO 100 (x , mm), is correlated with a smaller number of lambs born to related ewes in the first two reproductive seasons, REP 1 + 2 (Y), which is illustrated by the equation:

$$Y = -6.487x + 0.529 \quad R^2 = 0.43 \quad P = 0.02.$$

Tulley and Burfening (1983) found a similar dependence. This may be the result of the lower rate of ovulation during spring due to the short oestral period of the ewes. Knight (1984) obtained conflicting results and states that differences in assessing the relationship between testis circumference and fertility may result from both a weak relationship between measurements taken from young animals and those made on adults, as well as from the inadequate precision of measurement of small testis in the scrotum of lambs.

CONCLUSIONS

A greater testis diameter in 28-day-old rams and testicular circumference at the age of 100 days, measured in November and January, respectively, is correlated with delayed start of sexual activity of their half-sisters in May.

Testicular circumference at the age of 100 days was significantly negatively correlated with the prolificacy of ewes from paternal groups in the studied breeding seasons.

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STRESZCZENIE

Współzależność między użytkowością rozrodczą macierek a rozmiarami jąder spokrewnionych z nimi tryczków

Doświadczenie przeprowadzono na 395 maciorkach i ich 585 półbraciach w grupach ojcowskich (odpowiednio 50 i 37 grup). Badano termin występowania pierwszej rui u przystępek, termin skutecznego pokrycia starszych macierek i liczbę urodzonych jagniąt. U rosnących tryczków mierzono średnicę i obwód jąder w terminach stymulującego i hamującego działania długości dnia świetlnego. Na tej podstawie porównano cechy testometryczne tryczków z okresami aktywności płciowej i reprodukcją spokrewnionych z nimi macierek. Stwierdzono wpływ genotypu ojca na czas wystąpienia aktywności płciowej macierek w czasie stanówek wiosenno-letnich. Termin skutecznego pokrycia przystępek zależał istotnie ($P < 0.01$) od ich masy ciała. Stwierdzono istotną korelację ($\leq P < 0.05$; $r = 0.35$) między indeksem średnicy jądra tryczków w 28 dniu ich życia a okresem wystąpienia pierwszej rui przystępek oraz wysoce istotną korelację ($P \leq 0.01$; $r = 0.37$) między tym indeksem a okresem skutecznego pokrycia w pierwszym sezonie rozrodczym. Wykazano również istotne korelacje między indeksem obwodu jąder w 100 dniu życia a okresem, w którym nastąpiło zapłodnienie macierek ($r = 0.28$) w pierwszym sezonie rozrodczym i między tym indeksem a liczbą urodzonych jagniąt ($r = -0.27$) w pierwszym wykocie.