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BRIEF COMMUNICATION: Genetic and phenotypic parameters for stayability in a New Zealand research flock

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Introduction

Productive lifespan is important to commercial farmers, as ewes that are culled prematurely from the flock represent a considerable cost. The greater the number of replacements retained, the fewer the number of animals available for sale, and the greater proportion of the farm that must be allocated to rearing replacements at the expense of carrying more productive ewes. As selection occurs in stud flocks, Sheep Improvement Ltd. (SIL) developed an exit fate recording system that distinguishes between commercial culls of unsound sheep and the culling of sound sheep based on knowledge such as pedigree or genetic merit that would not usually be available to commercial breeders. Ewes culled for commercial reasons such as teeth, feet, udder problems, barrenness or low body condition are given a ‘C’ fate, sound sheep culled for knowledge reasons a ‘K’ fate or a combination ‘CK’ fate if applicable. An optional ‘C’ or ‘K’ sub-code can record the actual reason for culling, such as an udder fault.

Hudson & Van Vleck (1981) defined stayability (S) as the probability of an animal surviving to a specific age given the opportunity to reach that age. Most researchers use the first lambing or calving event as the base level, and express stayability as a binary trait with ‘1’ indicating presence or ‘0’ indicating absence at later lambing/calving events. For example ‘S (4|1)’ is the probability of a fourth calving given the cow had a first calving, as used by Snelling et al. (1995).

A second measure is marginal stayability (MS), given an animal's presence at a particular calving/lambing ‘n’, it is expressed as the probability of being present at the subsequent calving/lambing ‘n+1’. For example ‘MS(5|4)’ is the probability of being present at the fifth calving/lambing given the cow/ewe was present at the fourth.

A third measure of stayability is the ‘productive lifespan’ which can be measured as the number of calving/lambings or productive years/days in the herd or flock. This value only uses data on individuals that have died or exited (Borg 2007).

The aim of this study was to determine the genetic parameters for stayability in a New Zealand flock based on the SIL recording system. This paper expresses stayability relative to the first lambing at two years of age, for example, stayability to four years given a first lambing at two years of age is expressed as S(4|2) and marginal stayability at four years given presence at three year old lambing as MS(4|3).

Materials and methods

Since the year 2000, exit fates have been recorded for ewes in the Woodlands Research flock (SIL Flock 2638). There were 3,206 ewe records of which 1,281 were commercial culls (C), 747 were knowledge culls (K), 49 were a combination CK fate, 121 were an unknown code (U), 544 ewes were gone with no exit fate and records of 464 currently alive ewes. CK ewes were combined with C to give a total of 1,330 informative records. Stayability to an age was derived from lambing and pregnancy scanning records and was recorded as ‘1’ for present meaning they had a pregnancy or lambing record, and ‘0’ for absent meaning they had no pregnancy or lambing record. Marginal stayability was recorded as ‘1’ for present and ‘0’ for the year of culling, followed by an asterisk indicating missing in subsequent years. Alive ewes or exited ewes with no recorded fate were given a ‘1’ for being present if there was a lambing record for an age, followed by an asterisk for later ages so their data would not be used in the calculation of stayability at later ages. Productive lifespan was based on the age at last lambing for the 1,330 ewes with C or CK exit fates.

There was a relatively high rate of culling for both commercial and knowledge reasons in Flock 2638, with an average number of lambings per ewe entering the flock of 2.04, compared to an average of 2.23 to 2.42 lambings per ewe in 10 similar Romney/Coopworth flocks.

Statistical analysis

Fixed effect models were determined using the general linear model procedure (SAS 2004) to test for significance. Two standard fixed effect animal models were analysed with ASReml3 (Gilmour et al. 2009) for stayability and marginal stayability traits at each age, using derived binary data, and for productive lifespan based on age at last recorded lambing. Two fixed effects models were used in ASReml3. Model 1 fitted year of birth, age of dam, ewe birth and rearing rank as is used for a number of SIL modules, live weight at 18 months of age and litter size at two years of age. Model 2 fitted year of birth, age of dam, and ewe birth and rearing rank as is used for a number of SIL modules. Live weight at 18 months of age was excluded from the second model, although it was highly significant, due to the low number of flocks that record this trait. ASReml3 was used to generate estimated breeding values and accuracies for 7,329 individuals born from 2000 to 2009. As stayability and marginal stayability were set up as binary traits, the breeding value units were expressed as proportions. These values can be multiplied by 100 to be expressed as a percentage to be more meaningful to breeders.

Results

Year of birth was highly significant ($P < 0.001$) for all stayability and marginal stayability ages. Litter size at two years of age was highly significant for S(3|2), S(4|2), S(5|2) and MS(3|2) and significant ($P < 0.05$) for S(6|2) and MS(5|4). Live weight at 18 months of age had a significant effect on stayability for S(3|2), S(4|2), S(5|2) and S(6|2). It also had a significant effect on marginal stayability for MS(3|2) and MS(4|3). Every kg increase at live weight at 18 months of age was associated with an improvement of 0.5 to 0.9% in stayability. Ewe birth rank was significant for all stayability ages and for marginal stayability at MS(3|2) and MS(6|5).

Stayability

Heritability estimates of stayability for Model 1 ranged from 0.15 ± 0.04 for S(3|2) to 0.11 ± 0.04 for S(6|2) compared to 0.20 ± 0.04 for S(3|2) to 0.13 ± 0.04 for S(6|2) for Model 2 (Table1). Genetic correlations between consecutive years were high at between 90% and 95% for both models for adjacent lambings and decreasing as the lambings became further apart. The statistical analysis gave Model 1 fixed effects as the best fit, although Model 2 would be applicable to a greater number of SIL flocks.

Marginal stayability

Marginal stayability gave a similar pattern of heritability estimates and genetic and phenotypic correlations as stayability at the same lambing and same age (Table 2) but at slightly reduced levels as the ages for the two measures diverged, except for MS(5|4) which was lower than expected. This appears to be a real effect of the dataset. Marginal stayability uses fewer records in the estimation of values than stayability at the same lambing and same age. Stayability S(6|2) had 1,491 usable records compared to 508 for MS(6|5) which is reflected in the high standard error for MS(6|2). Phenotypic correlations were close to zero.

Table 1 Estimates of heritability ± standard errors (bold text on diagonal), phenotypic (above diagonal) and genetic (below diagonal) correlations for stayability (S) given being present at the two-year-old lambing. S(3/2) = Probability of a ewe lambing at three years of age after lambing at two years of age; through to S(6/2) = Probability of a ewe lambing at six years of age after lambing at two years of age. Fixed effects for Model 1 = Year of birth, Age of dam, Ewe birth and rearing rank, Live weight at 18 months of age and Litter size at two years of age. Fixed effects for Model 2 = Year of birth, Age of dam, and Ewe birth and rearing rank.

	Model 1				Model 2			
Stayability	S(3|2)	S(4|2)	S(5|2)	S(6|2)	S(3|2)	S(4|2)	S(5|2)	S(6|2)
S(3|2)	**0.15 ± 0.04**	0.64 ± 0.01	0.43 ± 0.02	0.29 ± 0.02	**0.20 ± 0.04**	0.68 ±0.01	0.47 ± 0.02	0.32 ± 0.02
S(4|2)	0.90 ± 0.07	**0.13 ± 0.04**	0.66 ± 0.01	0.43 ± 0.02	0.95 ± 0.04	**0.18 ± 0.04**	0.68 ± 0.01	0.46 ± 0.02
S(5|2)	0.72 ± 0.13	0.94 ± 0.06	**0.12 ± 0.04**	0.65 ± 0.02	0.82 ±0.09	0.95 ± 0.04	**0.15 ± 0.04**	0.65 ± 0.02
S(6|2)	0.66 ± 0.17	0.87 ± 0.12	0.95 ± 0.08	**0.11 ± 0.04**	0.75 ± 0.10	0.87 ± 0.10	0.95 ± 0.06	**0.13 ± 0.04**

Table 2 Estimates of heritability ± standard errors (diagonal), phenotypic (above diagonal) and genetic (below diagonal) correlations for marginal stayability (MS). MS(3/2) = Probability of a ewe being present at three years of age given that she was present at two years of age; through to MS(6/5) = Probability of a ewe being present at six years of age given that she was present at five years of age. S(3/2) = Probability of a ewe lambing at three years of age after lambing at two years of age; through to S(6/2) = Probability of a ewe lambing at six years of age after lambing at two years of age. Fixed effects for Model 1 = Year of birth, Age of dam, Ewe birth and rearing rank, Live weight at 18 months of age and Litter size at two years of age. Fixed effects for Model 2 = Year of birth, Age of dam, and Ewe birth and rearing rank.

	Model 1				Model 2			
Stayability	MS(3|2)	MS(4|3)	MS(5|4)	MS(6|5)	MS(3|2)	MS(4|3)	MS(5|4)	MS(6|5)
MS(3|2)	**0.15 ± 0.04**	0.00 ± 0.04	0.00 ± 0.05	0.00 ± 0.06	**0.20 ± 0.04**	0.01 ± 0.04	-0.00 ± 0.05	0.00 ± 0.06
MS(4|2)	0.52 ± 0.24	**0.09 ± 0.04**	-0.03 ± 0.05	0.01 ± 0.06	0.72 ± 0.19	**0.10 ± 0.04**	-0.02 ± 0.05	0.01 ± 0.06
MS(5|2)	0.28 ± 0.37	0.88 ± **0.41**	**0.05 ± 0.04**	-0.05 ± 0.06	0.36 ± 0.36	0.92 ± 0.04	**0.05 ± 0.04**	-0.06 ± 0.06
MS(6|2)	0.68 ± 0.42	0.49 ± 0.51	0.30 ± 0.64	**0.09 ± 0.09**	0.65 ± 0.30	0.43 ± 0.39	0.35 ± 0.55	**0.15 ± 0.04**

Productive lifespan

Productive lifespan based on the 1,330 ewes with a 'C' exit fate had a heritability of 0.20 ± 0.05 for Model 1 and 0.23 ± 0.06 for Model 2. The average age at culling for 'C' coded ewes was 3.48 years.

Breeding values

Breeding values for stayability S(3|2) averaged 0.03 with a standard deviation of 0.06. Accuracies averaged 41% with a standard deviation of 13%, and ranged from 9% for a sire with no ewes in the flock to 90% for a sire that had 117 daughters of which 58 had 'C' exit fates. Stayability breeding values for S(4|2), S(5|2) and S(6|2) averaged 0.04, 0.03 and 0.02 with standard deviations of 0.08, 0.07 and 0.05 respectively. The 2005 born animals that had two recorded lambing events in the flock, had S(4|2) breeding values that ranged from 0.28 to -0.14 with an accuracy of 17% to 20%, compared to S(4|2) values ranging for 0.12 to -0.06 for the 2009 born un-lambed age group, although accuracies levels were similar.

Discussion

The Woodlands flock has a young age structure, with many ewes culled at a young age based on a low index or breeding value as well as normal commercial culling based on barrenness, teeth, feet and udder conditions, low live weight or low condition score.

The results achieved from this study using the 'C', 'K' and 'U' exit fates to distinguish between commercial and knowledge culls, gave results similar to other analyses of stayability in cattle and sheep where individuals exited due to death or culling on failure to get pregnant, health and physical soundness. Snelling et al. (1995) estimated heritability of stayability in two beef herds as the probability of presence at the nth calving given a first calving S(n|1). The derived estimates were 0.09, 0.11, 0.07 and 0.20 for S(2|1), S(5|1), S(8|1)and S(11|1) respectively. A study of Hereford cows by Martinez et al. (2005), where cows were only culled for barrenness, serious unsoundness or failure to rear a calf for two consecutive years gave heritability estimates for productive lifespan of 0.05 to 0.15. Mekkawy et al. (2009) estimated longevity heritability at 0.27 based on commercial cull practises or death in Mule sheep. Reasons for culling were also recorded, with teeth or mouth faults having the highest heritability at 0.15. Brash et al. (1994) and Borg et al. (2009) reported lower heritabilities of 0.06 and 0 to 0.09 respectively in sheep.

This work needs to be repeated with a larger dataset to verify and refine the genetic parameters. There is a need to develop economic models to determine the economic value of stayability to different ages. This will assist in determining whether the focus should be on reducing cull rates of younger ewes using measures such as S(3|2) and S(4|2), or stayability to older age breeding values, or a combination of both. Stayability S(4|2), or a combination of S(3|2) and S(4|2), may optimise the number of records in the analysis by incorporating most censored records, as well as having the largest range of breeding values relative to the other ages, and has a high correlation with S(5|2) and S(6|2). As there is always a trade off in stud flocks between longevity and generation interval, a measure at a younger age designed to ensure ewes are not culled early in life may be a good solution given the high genetic correlations between stayability at younger and older ages.

Breeding values for older sires with many daughters in the flock can be very accurate at 80% to 90%, but for young animals available for selection into the flock, breeding values were concentrated around the mean with a limited spread of values and a low accuracy of 18% to 20%, relative to other traits. For example; number of lambs born based on the same number of female relatives available for stayability information, but with multiple lambing records per ewe, typically has an accuracy of around 35% to 45% based only on parent information as for the 2011 born animals in the SIL-ACE across flock analysis (S-AN Newman, Unpublished data). As longevity is recorded later in life and only in ewes, it would be very useful to develop a DNA based test for more timely selection information. This would require good phenotype records by breeders using the SIL coding system.

Heritabilities and correlations need to be confirmed in a larger dataset but this pilot study indicates useful levels of heritability and high correlations between stayability to different ages using the SIL system to distinguish between commercial assessed 'unsound' and knowledge assessed 'sound' culls. The use of sub codes for particular reasons for culling such as bearings, teeth and udder issues, may also allow genetic aspects of such conditions to be defined in future.

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