

Variance component estimation for reproductive merit of beef cattle using linear and non-linear models

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Abstract

An objective was defined for a breeding program in South Africa to improve the female fertility of the national herd. The aim of the study was to change the approach of defining a trait based on female fertility and to define the trait, reproduction merit, as an indicator of the efficiency of male animals as sires in a given population. Reproductive merit reflects the retention of male animals in a given population, but has the added advantage that it will also yield information on the reproduction performance of a sire's female offspring in that population. Data was extracted from the INTERGIS (Integrated Registration and Genetic Information System) for the Afrikaner beef breed in South Africa. Only data of females of sires older than nine years were included in the data to estimate the variance components, in order to give all sires an equal opportunity to have female offspring presented in all five categories. Effects included in the models were a breeder*year of birth*season (h*y*s) concatenation. For the linear analysis h*y*s was included as either fixed or random. Sire variances, using non-linear and linear models, were estimated as 0.06 (GFCAT), 0.052 (REML, h*y*s fixed) and 0.063 (REML, h*y*s random). The correlation between the solutions for the two REML models (fixed or random) was 0.73. Correlations between solutions from GFCAT and REML with h*y*s fitted as fixed or random were 0.99 and 0.73 respectively.

Keywords: Female fertility, heritability, retention, sire model

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Introduction

Reproductive efficiency is a function of the reproductive ability of each cow, but it is also affected by the age structure of the herd. Trying to understand a composite trait such as overall reproductive performance (ORP) can involve two approaches. Firstly, the trait to be investigated could be ORP itself or, secondly, components contributing to it could be considered (Rust & Groeneveld, 2001). Rust & Van der Westhuizen (1995) and Rust & Groeneveld (2001; 2002) investigated various traits in an attempt to describe ORP. Although calving rate (CR) as described by Rust & Van der Westhuizen (1995) comes close to ORP, it does have deficiencies. The current recording scheme of the National Beef Cattle Improvement Scheme (NBCIS) of South Africa was implemented in 1959. Reproduction information on cows can only be derived from birth notifications and weight records of their offspring. Data yielding information on retention and the reproduction rate of females in the national herd are confounded, and because the data were not recorded for the purpose of describing reproduction performance, indistinguishable. An objective has to be defined for a breeding program in South Africa to improve the female fertility of the national herd. The objective is to maximize the number of calves born or weaned for a given number of cows in a herd under the prevailing environmental and management conditions.

In this study, reproductive merit will be defined as a composite trait describing both the retention of male animals as well as the reproductive performance of their female offspring. The aim is thus to define reproductive merit as a trait and estimate variance components for it, to determine whether the trait can be improved genetically through selection.

Materials and Methods

Data were extracted from the INTERGIS (Integrated Registration and Genetic Information System) for the Afrikaner beef breed in South Africa. All female animals in the national Afrikaner herd were allocated to one of five categories according to the number of births se recorded as dam before the age of six years. The cut-off date of six years was chosen arbitrarily, suggesting that by the age of six one should have been able to establish whether a cow is a good breeding animal or not.

All females that never recorded the birth of a calf in the national herd were allocated to category 0. This category includes the young animals, too young yet to have produced a calf as well as older females that have no record of calving. It thus includes females never selected for breeding as well as females selected for breeding that failed to produce a calf. All females that recorded one calf up to the age of six years were allocated to category 1. This is one birth recorded at any age of the cow, as long as the age does not exceed six years. This category will also include females younger than six years that have not yet had the breeding opportunity to record the birth of more than one calf, but given more breeding seasons the possibility remains that they will potentially have more calves. The same principle was followed for all other categories; namely, category 2 females recorded two calves before the age of six years. It will include females too young to have recorded more than two calves, but given more breeding opportunities they theoretically have the possibility to improve their category. Category 3 animals calved three times before the age of six years but also including females too young to have produced four calves, and category 4 animals calved four or more times before the age of six years. Females used as embryo donors were omitted from the data. Only female offspring of sires older than nine years were used to estimate the variance components, in order to give all sires an equal opportunity to have female offspring present in all five categories. After editing, records of 18739 Afrikaner females from 766 sires were used to estimate variance components for reproductive merit. They were classified into the five different categories as described, with 8737, 2433, 3566, 3577 and 425 females categorized as category 0 to category 4 respectively.

Fixed effects included were a breeder*year of birth*season (h*y*s) concatenation. Seasons were classified as season 1 (Dec - Feb), season 2 (March - May), season 3 (June - Aug) and season 4 (Sept - Nov). There were 1 014 h*y*s levels present in the data. Genetic parameters were estimated using the GFCAT sire model set of programmes, developed by Konstantinov (1992), based on the threshold model, with support for REML-type variance component estimation derived from the methods of Gianola & Foulley (1983). All available sire relationships were taken into account.

The REML VCE4 package (Groeneveld, 1994a, b; Groeneveld & García-Cortés, 1998) was used to estimate sire variances using a REML sire model.

Results and Discussion

It was evident that 46% (8737 out of 18739) daughters of the 766 sires were never utilized as breeding females in the national herd. To large extends the preference of farmers for specific phenotypes (likeability) often determine whether females are selected for breeding or not. A minority of cows may have been selected for breeding, but never contributed a calf to the database. From those that were selected for breeding and that produced \geq one calf (10002 females) 24% recorded only one calf, 36% two, 36% three while 4% recorded four calves. The percentage of females for the Afrikaner breed that achieved the top category is small. For other breeds this percentage may be higher than 10% of females. To understand why this is so low for the Afrikaner one must understand how and where the Afrikaner is bred. The Afrikaner is a hardy breed used almost exclusively for extensive farming. Breeding of heifers usually only commences later after heifers reach a weight of 320-340 kg. This is generally reached at the age of 2½ years, thus extending the age at first calving to later than in some other breeds.

The sire variance and derived heritability estimates for reproduction efficiency using non-linear GFCAT and linear REML sire models are presented in Table 1.

Table 1 Variance components, heritabilities and general statistics of the non-linear GFCAT and linear REML VCE 4 analyses with h*y*s included as either fixed or random

	GFCAT	REML (h*y*s fixed)	REML (h*y*s random)
Sire variance	0.06	0.052±0.004	0.063±0.006
Derived heritability (h²)	0.23	0.20	0.24
Number of equations		2704	2704

h*y*s = herd*year*season concatenation

When using field data, Meijering & Gianola (1985) concluded that sire solutions obtained by REML and GFCAT were highly correlated ($r = 0.99$) for dystocia (4 categories) as well as for stillbirths (2 categories) recorded in the birth-recording program in the Netherlands. Matos *et al.* (1997) concluded that

the goodness of fit of REML and non-linear models for discrete reproduction traits of sheep was similar, and with respect to prediction ability, differences between the models were negligible.

The distribution for reproductive merit is skew, and the data are thus not best suited for fitting linear models. Other authors did, however, estimate variances for traits with a skew distribution, such as dystocia, stillbirth and calving ease, using linear models. Using non-linear and linear models, Hagger & Hofer (1990) estimated correlations ranging from 0.97-0.99 between the solutions for dystocia and stillbirths for three beef cattle breeds. To try and account for the heterogeneous variances in the h*y*s subclasses, the effect of h*y*s was included in the linear model as either fixed or random. Hagger & Hofer (1990) concluded that non-linear models were very sensitive to a herd*year effect as either fixed or as random, but using REML the estimates were all very similar for the herd*year effect as either fixed or random. In this study we found negligible differences in the estimated variance components and ratios when including h*y*s as either fixed or random, but the solutions differed significantly. The correlation between the solutions for the two models (fixed or random) was 0.73. Correlations between GFCAT and REML with h*y*s fitted as fixed and with h*y*s fitted as random were 0.99 and 0.73 respectively. Since fitting h*y*s as fixed correlated best with the results obtained from GFCAT it is suggested that h*y*s should be fitted as fixed when using REML. Few heritability estimates are available in the literature for reproductive traits and the authors did not find any trait similar to reproductive merit to compare the obtained sire variances with. The obtained sire variances show that the trait is heritable and that it should therefore respond to directed selection.

Conclusion

For any breeder it is an added advantage to have an indication as to how 'successful' a sire is expected to be as a breeding sire in a given population. Reproductive merit is a trait that estimate not only the retention of a sire's female offspring in the national population, but gives added information by taking the calving performance of a sire's female offspring into account when predicting a breeding value for that sire. Despite its obvious shortcomings, the trait (as defined) gives some indication of the reproductive merit of sires. The obtained results show that the trait is heritable and can therefore be improved by selection. Further investigation is needed on how to include data from sires younger than nine years of age as well as how to compensate for females too young to have reached their full breeding potential.

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