GENETIC PARAMETERS FOR ALTERNATIVE MEASURES OF FERTILITY IN A COMMERCIAL HERD OF TROPICAL COWS

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SUMMARY

Fertility efficiency is associated with increased profit being an important objective of breeding programs. Cow fertility is complex and difficult to improve. In this study we use the genomic relationship matrix (**G**) and REML approaches to investigate the genetic parameters for number of calves (NC) and fertility indices in tropical beef cattle. The fertility indices proposed were: $I_1 = NC/NO$, $I_2 = (NC/NO)*NC$ and $I_3 = (NC/ALC)*NC$, where: NO = Number of opportunity, ALC = Age at last calve. Heritability estimates of 22% to 24% were observed for the four phenotypes. The genetic and residual correlations were close to unity, except for those pairs that included I_1 in this case, correlations were around 0.50. We conclude that NC is an efficient selection criteria for the improvement of fertility in Tropical Composite cattle.

INTRODUCTION

An important goal of tropical beef cattle breeding programs is to improve reproductive performance. However, cow fertility is complex and difficult to improve because of low heritability, delayed expression in females' life and difficulties in the routine recording of phenotypes such as pregnancy status, days open and days for first service, especially in extensive large-scale tropical beef operations. Cow longevity, an indicator of fertility, has been evaluated in some beef cattle breeding programs. However, selection for improved longevity is challenging because this trait is only available after the cow is culled or dead. Additionally, the observation results in censored data or binary distribution which requires complex statistical analyses. Alternatively, fertility indices that shows the abilities of the female to calve at a young age, to maintain the regularity of calving, and to wean heavy calves (Eler *et al.* 2008) might be advantageous because it permits the evaluation of genetic merit of females with only one or few calving events as well as the evaluation of young bulls (Santana *et al.* 2013). However, number of calves (NC, with cow age as a fixed effect in the statistical model) might be a simple and efficient predictor of cow's fertility. Thus, we propose this measure of fertility, which was less demanding and also easy to understand and can be useful for improving the fertility of the breed. In this study we make use of the genomic relationship matrix (**G**) to estimate genetic parameters for number of calves and fertility indices in a commercial herd of Tropical Composite cows in Australia.

MATERIAL AND METHODS

Phenotypic and genotypic data. The data set used in the present study consisted of 1,166 commercial Tropical Composite cows from North Australian Pastoral Company (NAPCO) with phenotype records including the number of calves (NC) and three alternatives fertility indices (Table 1 and Figure 1). The fertility indices explored were as follows: $I_1 = NC/NO$, $I_2 = (NC/NO)*NC$ and $I_3 = (NC/ALC)*NC$, where: NO = Number of opportunity, ALC = Age at last calve. The I_1 index is related to reproductive efficiency of females, the value 1 or 100% was attributed for females that calving in all breeding opportunities and the indices I_2 and I_3 benefit the females that remain in the herd for longer periods of time (longevity). Genotypes were generated based on a panel with

approximately 54,000 polymorphisms from the Illumina BovineSNP50. The following criteria were used for the exclusion of SNPs: minor allele frequency less than 2%, call rate less than 90% and/or duplicate samples. After quality control, 42,455 SNPs remained for analysis.

Table 1. Descriptive statistics results for reproductive traits in Tropical composite cows

Traits	Number of observation	Mean $\pm$ sd	Min	Max
Age of dam	1,166	6.17 ± 3.16	3.00	19.00
I_1 = NC/NO	1,166	0.667 ± 0.249	0.00	1.00
I_2 = (NC/NO)*NC	1,166	2.783 ± 2.94	0.00	15.00
I_3 = (NC/ALC)*NC	1,166	2.26 ± 2.62	0.00	13.24
NC	1,166	3.48 ± 3.12	0.00	15.00

NP = Number of calves, NO = Number of opportunity, ALC = Age at last calve.
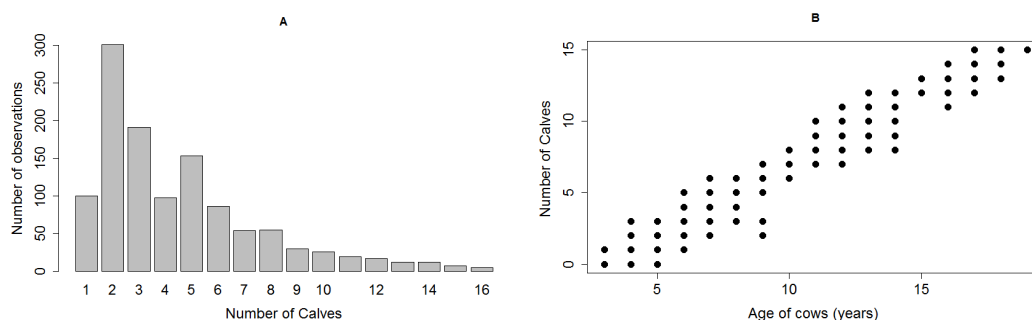

Figure 1. Distribution for number of calves (A) and distributions for number of calves by age of cows (B)

Statistical analysis. A tetra-variate analysis was performed using the general mixed model in $y_{ij} = X\beta + Zu + e_{ij}$, where: y_{ij} represents the phenotypic observations from the *i*-th cows ($i = 1$ to 1,116) at the *j*-th phenotype ($j = 1$ to 4), X is the incidence matrix relating fixed effects in β with observations in y_{ij}, Z is the incidence matrix relating random additive polygenic effects in **u** with observations in y_{ij}, and e_{ij} is the random residual effects. Fixed effects included in the model were contemporary group (i.e., cohort of cows born in the same year and raised together) and group of age of the dam. Solutions to the effects in the model as well as variance components were estimated using **G** according to Wang *et al.* (2014) in BLUPF90 programs (Misztal *et al.* 2009).

RESULTS AND DISCUSSION

Variance components, heritability and genetic and residual correlations are reported (Table 2). Moderate heritability estimates of $\sim 22\%$ were observed for the four phenotypes. The heritability estimate for number of calves was higher than those reported by Martinez *et al.* (2004) and Zhang *et al.* (2013) for number of calves born in Hereford (h^2 = 0.15), Brahman (0.15) and Tropical Composite cows (0.14). Martinez *et al.* (2004) and Zhang *et al.* (2013) evaluated the lifetime number of calves in predetermined age of cows and determined heritability estimates using **G**. These results demonstrate that **G** often explains more genetic variance than the pedigree-based estimates. In fact, heritability for number of calves at 6 years were 0.22 and 0.16 with **G** and 0.15 and 0.14 with pedigree-based matrix for Brahman and Tropical Composite cows, respectively (Zhang *et al.* 2013).

Table 2. Genetic parameters of reproductive traits in Tropical Composite cows, last 4 lines: heritability (diagonal), genetic correlation (above diagonal) and residual correlation (below diagonal) by single-step-genomic-BLUP methodology

	I_1 = NC/NO (%)	I_2 = (NC/NO)*NC	I_3 = (NC/ALC)*NC	NC
Genetic variance	0.008	0.241	0.490	0.265
Residual variance	0.029	1.922	1.639	0.921
I_1 = NC/NO (%)	0.22	0.52	0.48	0.56
I_2 = (NC/NO)*NC	0.54	0.24	0.99	0.99
I_3 = (NC/ALC)*NC	0.49	0.99	0.23	0.99
NC	0.57	0.99	0.99	0.22

NC = Number of progeny, NO = Number of opportunity, ALC = Age at last calve.

According to Chud *et al.* (2014) the low heritability estimate for fertility indices might be related to low heritability estimates for traits such as NC and ALC that compound the index. Actually, the heritability for age at calving was low, ranging from 0.05 to 0.15 over 1 to 6 calving seasons, respectively (Martinez *et al.* 2004). Furthermore, the heritability for other reproductive traits were lower than the values obtained in this study, mean and standard errors (in brackets) of 0.12 (0.07), 0.06 (0.06) and 0.11 (0.07) were obtained for conception, pregnancy and calving rates, respectively, in Tropical Composite cows (Johnston *et al.* 2013). Thus, it is possible to achieve higher genetic progress across generations through selection for NC or fertility indices evaluated here than others reproductive traits, since the heritability of NC or fertility indices were greatest.

It is important to highlight that a positive correlation between ratio values, as a fertility indices proposed here, reduces the selection response of both traits, but mainly for the trait with the weaker ratio position (Essl, 1989). That is the numerator if selection is for higher ratios and the denominator in the opposite case. Moreover, the difference between the relative selection responses for the single ratio traits becomes more diferent the closer their genetic correlation is to +1 (Essl, 1989). Thus, the ratio values can be used as a selection criteria in breeding programs however, the genetic correlation between traits included in the ratio should be strictly and routinely evaluated. Because genetic correlations change across generations, pleotropic genes may be fixed and linkage may be lost (Sheridan and Backer, 1974). However, traits can be combined in an index which included economic values (Hazel, 1947).

The genetic and residual correlations were close to unity, except for those pairs that included I_1, in this case correlation were around 0.50. Therefore, genetic progress for longevity (I_2 or I_3) can be achieved through selection for NC or fertility efficiency (I_1), which might be measured in early female's life. The length of productive life measured through 1 year after first calving in Hereford cows predicts productive life through 6 years with reasonable accuracy (Martinez *et al.* 2004). Selection for younger age at puberty leads to increase in lifetime reproductive performance of Brahmam (rg = –0.40 ± 0.20) and Tropical Composite (rg = –0.33 ± 0.28) cows (Johnston *et al.* 2013).

CONCLUSION

Based on estimates of heritability and genetic correlations, the number of calves could be a simple and useful selection criterion for improving the fertility of Tropical Composite cows in commercial operations.

Poster presentations

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