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Angus selection herd reproductive data: a genetic model for dairy cattle?

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ABSTRACT

A selection experiment with Angus cattle, established in 1984/85, has achieved a difference in age at puberty in heifers of 70 ± 6 days (17%) between an 'Age Plus' (i.e. high age) selection line and an 'Age Minus' line. Currently three heifer calf crops (born in 1993-95) are being retained until 5.5 years of age, so that pregnancy rates in 5 mating seasons (and calving data in 4 seasons) on unculled females can be recorded. Genetic correlations between pubertal traits (from either sex) and heifer or cow reproductive traits have been calculated. Similar estimates were also derived from a pilot beef-cattle trial in 1980-85 using paternal half-sib data (230 sire groups), but no selection. The objective of this paper is to evaluate the merits of selecting on pubertal traits to improve reproduction, and to assess the possibilities of this type of selection in dairy cows.

Correlated responses in the 'Age Minus' herd, relative to 'Age Plus', include earlier pubertal development in half-brothers (+1.6 cm (5.2%) in scrotal circumference (SC) at 8, 10 and 12 months of age, P<0.001), an earlier mean calving date in cows by 3 days following an unchanged start-of-mating date, a 3-day reduced postpartum anoestrous interval (PPAI, adjusted for the earlier calving date), and a higher mean pregnancy rate (+4.7%, based on 1083 matings) in cows 2 years of age or more (P < 0.05).

All the genetic correlations between age at puberty in heifers and cow reproductive traits in our two studies so far have favourable signs (e.g. negative between age at puberty and pregnancy rate, or positive between age at puberty and PPAI), so that selecting heifers for earlier pubertal age would be consistent with increasing cow reproduction. Because selecting heifers for puberty is not very practical, selecting bulls could be more realistic. All the genetic correlation estimates between SC and cow reproductive traits in our two studies so far also have favourable signs. Additionally, genetic correlations between SC in bulls and age at puberty in heifers are negative (-0.21 ± 0.09 and -0.19 ± 0.20, respectively in the two trials cited above), so that bull selection for higher SC would reduce age at puberty in heifers and improve cow reproduction. Thus direct selection for precocious puberty in our Angus herd (predominantly by bull selection) has led to more fertile beef cows. It is suggested that the genetic correlations observed could be an initial model for dairy cattle, showing how selection-index traits on dairy animals at puberty could be used to correct for the inferior reproductive genes of some dairy cows.

Keywords: Angus; puberty; reproduction; genetic-correlation; pregnancy-rate.

INTRODUCTION

A genetic selection experiment was established with Angus cattle in 1984/85 to study pubertal traits and their relationships with cow reproductive traits (Morris *et al.,* 1993b). The experiment has now reached the third generation of cows and the fourth generation of calves, with the opportunity to evaluate overall pregnancy rate and its component traits, such as the interval from calving to first oestrus (PPAI), and calving date itself. The objective of this paper is to summarise these observed correlations, and others from an earlier pilot trial, in order to consider their possible relevance to the genetics of dairy cattle reproduction.

MATERIALS AND METHODS

Pilot trial

A pilot trial was set up at Landcorp's Goudies Station, 60 km SE of Rotorua in 1979/80. Experimental calf crops were generated for a breed evaluation and crossbreeding project, with single-sire matings within breed, and there was also an opportunity to progeny-test sires in 6 calf crops both for scrotal circumference (SC) via sons and for age at puberty (first behavioural oestrus, AFO) via heifers. Being part of a breed evaluation, there was no directional selection, and thus any culling to reduce weaned-calf or yearling numbers entering the breeding herd was at random within herd. All details of the experimental design for recording calves and yearlings of each sex were described by Morris *et al.,* (1992), and the subsequent evaluation of heifers and cows for reproductive traits was described by Morris and Cullen (1994). Calves were born in September/October each year. Bull calves were measured 3 times for SC, at 8 months (May), 11 and 13 months of age. Heifer calves each year were recorded for puberty from May until December, using paint marks from bulls fitted with chinball harnesses. Until the start of mating in November the bulls were vasectomised animals; thereafter they were entire bulls. The date of first behavioural oestrus was defined as the date of the first harness mark, from which AFO and standardised age (SFO, defined later) were calculated. The heifers entered the breeding herd at 14 months of age and were retained for at least 4 calvings (5 years of age at last calving), with culling for non-pregnancy. Data were analysed within breed; details were given by Morris *et al.*, (1992). There were 1302 bull calves recorded (birth years 1980-85), and 1198 heifer calves (1981-85) for which an SFO record and subsequent mating data were recorded. These animals were the progeny of 256 sires over all 6 birth years, and of 230 sires over the last 5 years.

From the pilot study, the genetic correlations of SC with AFO and SFO were -0.39 ± 0.22 and -0.19 ± 0.20 respectively, whilst heritabilities for AFO and SFO were 0.33 ± 0.12 and 0.32 ± 0.10 respectively. Although not completed before the selection study began, the results led to the following conclusions: (1) that selecting heifers for/against SFO would change SFO, (2) that selecting bulls for/against higher SC would change SFO in heifers in the opposite direction (Morris *et al.,* 1992), and (3) that heifers with earlier puberty showed higher subsequent reproductive performance genetically (Morris and Cullen, 1994). The pilot study provided genetic correlation estimates from paternal half-sib data, whereas a selection study was needed to demonstrate that responses to selection could be achieved across generations, with selection-induced pubertal changes leading to cow reproductive changes.

Selection study

In the first phase of the selection experiment (1984/85 to September 1992), a trial was established with Angus cattle at Waikeria Farm, Te Awamutu, with three selected lines and an unselected control line all originating from the same foundation stock. Details were given by Morris *et al*., (1993b) and Morris and Wilson (1997). Briefly the lines were an SC line, a line (Age Minus) selected for reduced AFO in heifers using phenotypic selection against AFO, a line (Age Plus) selected for increased AFO in heifers using phenotypic selection for AFO, and a Control line in which no intentional selection for puberty was applied. Bull selection in the Age Minus and Age Plus lines was determined by the Waikeria owners, leading to some increases in 13-month weight adjusted for age of dam and age of calf.

In the second and current phase (1992 to the present), the experiment was transferred to AgResearch's Tokanui Station, Te Awamutu. The Control line was retained, and the following modifications were made to the selection lines: (1) the experiment was modified to concentrate on SFO, (2) the lines selected for SC and Age Minus were merged, using breeding values (BVs) for SFO to select elite cows (whilst reducing cow numbers), (3) most of the future selection pressure in the two remaining selection lines was to be applied via bulls, but (4) in principle either sex could be selected on BV for SFO. This was done by using SC data from any bull (his own record and those of all male relatives) and SFO data from any female (her own record and those of all female relatives), and combining these in an index derived from a bivariate restricted maximum likelihood (REML) animal model, with full relationship matrix (Johnson and Thompson, 1995).

The first 3 calf crops of heifers from the second phase (1993-1995 births) were/will be retained unculled for 5 matings and 4 calvings each, in order to collect calving and associated data. There were 1702 bull calves with SC records (1985-1997 birth years) and 1588 heifers with SFO records in the same years, the progeny of 225 sires (104 Age Minus, 57 Control and 64 Age Plus). The results of both phases so far are described in this paper.

Statistical methods

REML procedures were applied to the Goudies and selection-line data to estimate variance and covariance components, and to calculate associated BVs for bulls, cows and heifers (computer programmes from Johnson and Thompson (1995) and Gilmour (1997)). The selection-line comparisons of pubertal traits and calving dates or intervals were analysed using Genstat (1994), whilst pregnancy data were tested using chi-square. In the Age Minus and Age Plus selection line comparisons, the yearling traits consisted of data up to the 1996- and 1997-born calf crops, and the pregnancy rates of two-year-old-plus cows (1083 matings for the two selection lines) consisted of data from the1992/93 mating season to the1998/99 season. For AFO, a transformation was required (standardised age, SFO), to include animals which had not yet shown oestrus, by converting AFO records to standard normal deviates (with animals which had not reached puberty being given a fixed value exceeding the maximum age observed), as if AFO was an ordered categorical response (Gianola and Norton, 1981).

RESULTS

Table 1 shows the heritability and repeatability results from pubertal traits at Goudies and in the selection experiment. Heritabilities were of a similar magnitude for SC, AFO and SFO. For each trait measured on the same animals repeatedly, the repeatability estimate was appreciably larger than the heritability.

Table 1: Heritability and repeatability estimates for reproductive traits from two experiments.

Trait	Heritability Goudies	Heritability Tokanui	Repeatability Tokanui
Age at first oestrus	0.33 ± 0.12	0.31 ± 0.05	-
Standardised age at first oestrus	0.32 ± 0.10	0.30 ± 0.05	-
Scrotal circumference	0.29 ± 0.07	0.37 ± 0.05	0.74 ± 0.01
Pregnancy rate:			
yearling	0.04 ± 0.04	0.12 ± 0.05	-
2-year-old	-	0.08 ± 0.06	-
mixed age[1]	0.04 ± 0.07	0.04 ± 0.05	0.09 ± 0.04
Calving date	0.04 ± 0.09	0.09 ± 0.04	0.19 ± 0.03
Interval, calving to conception	-	0.11 ± 0.04	0.19 ± 0.03

[1]Matings for calvings at 2 to 6 years of age (Goudies), and calvings at 4 to 12 years of age (Tokanui).

Table 2 shows the genetic correlations between pubertal traits (male or female) and cow reproductive traits. Basically there were 2 types of genetic correlations, those with SFO where the genetic correlations were negative (e.g. earlier puberty leading to higher pregnancy rate), and those with SC where the genetic correlations were positive (e.g. higher SC in males, associated with female relatives having higher pregnancy rate). Table 2 also shows the correlated responses between the Age Minus and Age Plus lines. In all cases, the sign of the line differences was consistent with the genetic correlations shown in Table 2. Not shown is the herd difference in PPAI of -3.0 days (i.e. Age Minus earlier), again where the sign was consistent with expecta-

Table 2: Genetic correlation (R_g) estimates from two experiments, and differences between the Age Minus and Age Plus selection lines at Tokanui.

Trait	R_g with SFO[1]		R_g with SC		Difference "Age-"-"Age+"
	Goudies	Tokanui	Goudies	Tokanui	
Scrotal circumference	-0.19	-0.21	n.a.	n.a.	+ 1.6 cm
Pregnancy rate[2]	-0.76	-0.21 to -0.29	0.34	0.14	+ 4.7%
Calving date	0.10	0.57	-0.06	-0.25	-2.5 days

[1]SFO = standardised age at first oestrus; SC = scrotal circumference.
[2]Matings for calvings at 2 to 6 years of age (Goudies), and calvings at 3 to 12 years of age (Tokanui).

tion. The critical result was for pregnancy rate, where a 4.7% line difference was found ($P < 0.05$), in favour of the Age Minus over the Age Plus line females.

DISCUSSION

The critical fact about selection to change pregnancy rate is that, although direct measures of pregnancy rate tend to have low heritabilities, correlated traits such as pubertal traits have much higher heritabilities, and selection for puberty can improve pregnancy rate via the genetic correlation. This is shown in our two data sets, but it applies in other New Zealand data sets (e.g. within-breed data from an earlier phase of our breed comparisons, Morris *et al.,* 1993a). Results published by Hetzel *et al.,* (1989) for Queensland beef cattle show that it is even possible to progeny-test and select directly for pregnancy rate under extensive conditions, but pregnancy testing, single-sire mating and high selection intensities are required for this.

In the case of exploiting correlations with pubertal traits, the matrix of genetic correlations (Table 2) suggests that selection for higher SC and/or for lower SFO will lead to higher pregnancy rate, earlier calving date and shorter intervals after calving. Relative to a selection-line difference of 4.7% in pregnancy rate favouring Age Minus females, there was an associated 1.6 cm difference of SC favouring Age Minus line males, or a difference of 2.9% per cm. The corresponding relationship in the Goudies experiment was similar at 2.4% per cm.

An alternative to pubertal selection which has been promoted by Notter and Johnson (1988) and Johnston and Bunter (1996) is to select for reduced "days to calving" (i.e. earlier calving date). However, it is not clear if there will be any correlated response in gestation length and calf survival. Our selection-herd data, with natural matings and the recording of entire-bull mating marks 2 to 3 times a week, rather than daily, may not be sensitive enough to estimate gestational changes.

PPAI was reduced in the Age Minus herd. A recent British study in British Friesian dairy cows has established a heritability and repeatability for log PPAI of 0.21 and 0.26, respectively (Darwash *et al.,* 1997), with estimates of similar size to those in our data. They also calculated regressions of log PPAI on transmitting ability of the sire for milk, fat and protein (kg and percentage). With only 721 daughter lactations, they found one significant regression for fat percentage. This was positive indicating that higher PPAI was genetically associated with higher fat percentage; for example, daughters of a bull with a BV 0.31% above average for fat percentage would have a 6.5-day longer PPAI.

Other studies with dairy cattle under a variety of management conditions have led to similar conclusions. For example, Grosshans *et al.,* (1997) analysed data from seasonally calving dairy herds in New Zealand and obtained heritabilities for the interval from calving to first service (0.01 to 0.03), days open (0.01 to 0.02) and pregnancy rate to day 42 since the start of breeding (0.03); they reported that 'antagonistic genetic correlations existed between milk production and most fertility traits'. In Sweden, Oltenacu *et al.,* (1991) found heritabilities for first-service conception rate and numbers of services per pregnancy of first-lactation cows of 0.04 and 0.05, and genetic correlations between these and fat-corrected milk yield of -0.14 and 0.16, respectively. In Florida, Campos *et al.,* (1994) found heritabilities for calving interval and days open in Holsteins of 0.098 and 0.052, and genetic correlations of these with milk yield of 0.17 and 0.16; corresponding values for Jerseys were 0.021 and 0.026, 0.16 and 0.27, respectively. All of these data, from a variety of dairy cattle environments, seem to be pointing in the same direction (although single estimates from individual analyses were not necessarily significant), namely that selection for increased milk yield leads to poorer reproductive performance. In words from the New Zealand study by Grosshans *et al.,* (1997), 'fertility traits should be incorporated into selection programmes for dairy cows to counteract the antagonistic relationships between milk production and fertility'. A possible method for including reproductive traits could be by way of selection for pubertal traits.

It is concluded that selection to change pubertal traits in either bulls or heifers will change cow reproductive traits in beef cattle. A cost-benefit analysis for hill country beef farmers would show the benefits and costs of this form of selection. Data from dairy cattle have given similar (low) heritabilities for reproductive traits to those in beef cattle. It is suggested that the AgResearch experimental selection lines may be a useful initial model for studying both the genetics of reproduction in dairy cattle, and how reproduction will respond to puberty selection.

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