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Some genetic and non-genetic effects on the first oestrus and pregnancy rate of beef heifers

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ABSTRACT

Fourteen herd-years of data, comprising a total of 2169 records, were obtained from beef heifers involved in the Ruakura Genetics Section's long term breeding trials. The contributions of breed-cross, weight selection, herd-year, birth date and age of dam, to variation in live weight, proportion exhibiting oestrus and proportion pregnant were studied. For heifers reaching first oestrus by about 15 months of age, means ages and weights at puberty were also calculated. Later-born calves were younger and lighter at puberty than average. Younger dams produced heifer offspring which reached puberty when older but lighter than average. Breed and location differences were greater for proportions of heifers expressing oestrus before joining than for proportions pregnant. At Goudies, the proportion achieving oestrus among Jersey x Angus heifers was 0.72, Friesian-cross 0.61, Hereford x Angus 0.47, Hereford 0.38 and Angus 0.25. Corresponding proportions diagnosed pregnant after 8 weeks of mating were 0.83, 0.93, 0.83, 0.78 and 0.73. Where there were major feed shortages over an extended period between 5 and 15 months of age, live weights and pubertal age were more affected than pubertal weight. In contrast, long term weight selection increased pubertal weight by 11%, while pubertal age was little changed. Preliminary estimates of heritability for pubertal age and weight were 0.31± 0.19 and 0.45±0.19. From genetic correlation estimates, live-weight selection was expected to reduce pubertal age and increase pubertal weight.

Keywords Beef cattle; heifers; oestrus; puberty; pregnancy; live weight; heritability; selection; crossbreeding.

INTRODUCTION

There are currently few published data in New Zealand on breed and crossbred effects on the onset of first behavioural oestrus in beef cattle. Smeaton and Winn (1981) found a live weight at puberty in Angus and Friesian x Hereford heifers of 258 kg at Whatawhata, similar to that reported in America (Laster *et al.*, 1976; Angus, 255 kg and Hereford, 274 kg). A higher value has been reported in Australia by Morgan (1981) for Herefords (290 kg). Dalton *et al.* (1980) found a mean of 215 kg at puberty for Angus, and 202 kg for Angus x Friesian or Hereford x Friesian heifers in New Zealand.

The objective of the current work was to study more breed and crossbred differences, selection effects and some non-genetic factors affecting first oestrus and pregnancy rates in beef heifers under commercial New Zealand farming conditions.

MATERIALS AND METHODS

Experimental Herds

The data were collected over 14 herd-years from the Ruakura Genetics Section's long-term breeding trials, comprising a total of 2169 heifer records (Table 1). There were 4 locations:

(a) Goudies. Crossbred and straightbred heifers were compared as part of the interbreeding phase (heifers born 1981-83) of the Beef Breed Evaluation (Baker *et al.*, 1981). Five breed types are reported here;

(b) Flock House. Two crossbred types of heifers were compared with straightbred Angus (heifers born 1981-83). The trial design was given by Baker (1980);

(c) Waikite. Heifers from the Hereford weight selection (HS1), Angus weight selection (AS1, AS2) and control (ACO) herds (heifers born 1981-83) were evaluated from the weight selection experiment whose design was described by Baker *et al.* (1980);

(d) Waikeria. Angus selection heifers born 1979-83 were evaluated from the weight selection experiment up to 1981 (Carter *et al.*, 1980) and from the current selection experiment (first calving year, 1982), using 4 herds whose selection criteria involved combinations of live weight, age at puberty (heifers) and scrotal circumference (bulls).

The 4 locations provided examples of the effects on heifer puberty and pregnancy rate due to different breeds or crosses (using Angus as a reference breed), due to weight selection and control herds, and to 4 non-genetic factors, herd-year (n=14), birth date, age of dam (2-, 3-, 4- and ≥ 5-year olds) and, unintentionally, a drought affecting puberty of heifers born in 1982 at Goudies and in 1981 at Flock House.

Management Practices

Calves were born at mean dates of late August/early September (Table 1), with a within-herd calving spread of 10 weeks. Weaning was at a fixed date for each herd-year, averaging about 5½ months of age in February or March.

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Vasectomised bulls were fitted with chinball harnesses and run with heifers in one large management group per location, at about 1 bull to 30 heifers. Paint marks were recorded on heifers at a frequency of up to 3 times a week, either in the paddock or during routine operations in the yards. First behavioural oestrus (puberty) was defined as the date of the first intense paint mark when followed by another between 18 and 24 days later. Some latitude was allowed where it was likely that one oestrus record had been missed between 2 dates approximately 42 days apart if followed by regular cyclicity. However, heifers apparently marked and then anoestrous for an extended period were assumed not to have reached first oestrus. Because of different labour constraints among herds and years, the dates for starting and finishing records of oestrus varied widely. In general, teaser bulls were introduced at Waikeria in May, and at the other locations in June/early July. Recording at Waikeria (heifers born 1979-81), Waikite and Flock House terminated in October/November prior to mating in November, but continued with harnessed entire bulls at Waikeria (heifers born 1982-83) until January/February and with harnessed entire bulls at Goudies until mid-December.

At Waikite, as part of the main experimental design, AS1 and HS1 heifers were joined (6 bulls/strain), but AS2 and AC0 heifers were not joined as yearlings. For the 1983 AC0 herd however, the design was modified so that a random half of the heifers were also joined as yearlings. During mating, heifers at all locations were combined with cows in single-sire mating groups. At Waikeria heifers were in 14 single-sire groups, at Goudies ≥ 27 groups and at Flock House 12 or 13 groups. The mating period at each location was 8 weeks.

Age at oestrus was computed from oestrus date and birth date; weight at oestrus was estimated by interpolation from monthly or 6-weekly weights. Because of the narrow spread of birth dates of heifers and a recording period of 4 months which limited numbers of heifers observed at oestrus, the recording dates partly determined apparent age at oestrus, and to a lesser extent weight at oestrus. With the extended recording period at Waikeria, a large proportion (0.90) of heifers was observed with a first oestrus. Corresponding figures at Goudies, Flock House and Waikite were 0.73, 0.68 and 0.55 respectively. In contrast to oestrus age and weight, 2 other puberty variates were analysed which were not biased at any location by recording procedures, i.e.:

- proportions oestrous at fixes times (a. end of September, b. beginning of mating), and
- proportion diagnosed pregnant by rectal palpation (excluding those in any subfertile bull groups).

Statistical Analysis

Data from each location were treated separately. Harvey's (1977) computer programme was used to analyse data in 3 batches:

(a) all heifers, to estimate genetic and non-genetic effects on live weights and proportion showing first behavioural oestrus;

(b) all heifers that had shown oestrus, to analyse age and weight at oestrus; and

(c) a subset of (a), all heifers except those in subfertile bull groups or AS2 and AC0 heifers not mated, to estimate proportion diagnosed pregnant.

The statistical model included effects for breed or selection strain, year born, age of dam (4 classes) and a regression covariate for birth date within herd-year. For Goudies data, paternal half-sib heritabilities and genetic correlations were also estimated, by fitting sires within breeds.

RESULTS

Genetic Factors

Breeds and crosses

The Angus breed, replicated over the 4 locations, was used as a reference point. At Goudies (Table 1), puberty in Herefords occurred at a lower weight than in Angus ($P<0.05$), but neither age at puberty, live weights in June or October/November, nor proportions achieving oestrus or pregnancy differed significantly between the 2 breeds. The Hereford x Angus F1, F2 and F3 crosses performed midway between the parental breeds for age at puberty, but were similar to the heavier breed (Angus) for weight at puberty (7 kg above the parental average). They were superior to the Angus breed for live weight, oestrus and pregnancy traits (Table 1). However, the margin was significant only for proportion showing oestrus at the start of mating (0.22±0.08); the superiority of the crossbreds over the 2 straightbreds for this trait (+0.16) was sufficient to explain the increase in proportion pregnant (+0.08).

Compared with the Angus, the Friesian-cross (i.e. Friesian x Angus and Friesian x Hereford) heifers achieved puberty younger (-26±13 days) and at a similar weight, with significantly higher proportions ($P<0.01$) achieving oestrus or pregnancy (e.g. 0.20±0.07 more pregnancies). Jersey-crosses achieved even younger puberty and significantly lower weights at puberty and in June and October/November than all other breeds ($P<0.05$), but the proportion pregnant was intermediate between Angus and the Friesian-crosses.

There were significant breed x year interactions for the proportions showing oestrus in September ($P<0.05$) and at the start of mating (P=0.05), (with the Angus, Hereford and their crosses changing rank, but leaving the dairy-crosses ahead).

TABLE 1 Live weight, puberty and pregnancy data for heifers from 4 locations, after allowing for the effects of year, age of dam and birth date.

	No. of heifers	Mean birth date	Puberty age (days)	Puberty weight (kg)	Live weight (kg) June	Live weight (kg) Oct, Nov	Proportions[1] Oestrous (a)	Proportions[1] Oestrous (b)	Proportions[1] Pregnant[2]
Goudies[3]									
Angus	78	9 Sep	403	251	180	261	0.12	0.25	0.73
Hereford	52	21 Sep	391	229	171	260	0.16	0.38	0.78
Hereford-Angus[4]	104	13 Sep	397	247	184	268	0.23	0.47	0.83
Friesian-cross	155	16 Sep	377	249	197	282	0.40	0.61	0.93
Jersey-cross	75	9 Sep	339	206	178	249	0.58	0.72	0.83
Average breed SE[5]	—	—	9	6	2	4	0.05	0.06	0.05
Flock House[3]									
Angus	130	14 Aug	344	230	213	271	0.61	0.72	0.83
Blond d'Aquitaine-Angus	85	27 Aug	375	251	226	289	0.35	0.47	0.66
Ba J.A[6]	111	24 Aug	350	252	222	285	0.54	0.63	0.83
Waikite									
Angus Control	141	23 Aug	378	212	181	210	0.38	0.44	(0.75)[7]
AS2 herd	134	28 Aug	382	216	196	228	0.42	0.55	—
AS1 herd	170	27 Aug	382	236	205	238	0.42	0.58	0.90
Hereford HS1 herd	126	3 Sep	384	243	207	238	0.46	0.63	0.85
Waikeria Angus herd	808	1 Sep	359	261	220	275	0.68	0.72	0.78

1 (a) showing oestrus by September 30; (b) showing oestrus by close to the start of joining
2 Excludes subfertile bull groups; the analysis for this trait excluded birth date
3 Crosses were from F1, F2 and F3 generations
4 Hereford-Angus and Angus-Hereford results were combined; F1s comprised 29% of these data
5 Average of breed standard errors (SE), illustrated only for Goudies data
6 Ba J.A = ¼ Blond d'Aquitaine x ¼ Jersey x ½ Angus
7 1983 crop only; a random half (n = 24) was joined

Compared with the Angus at Flock House (Table 1), Blond d'Aquitaine x Angus heifers were not only heavier at set times (June, 13±3 kg; October/November, 18±4 kg), but were significantly older (31±8 d) and heavier (21±4 kg) at puberty. The pregnancy rate difference of 0.17±0.04 was not as wide as the difference in the proportion of heifers exhibiting oestrus at the start of mating (0.25±0.06). In the Blond d'Aquitaine-Jersey x Angus group (Ba J.A), substituting 25% Jersey for 25% Blond d'Aquitaine genes reduced age at puberty by 25±9 d and increased proportions of heifers achieving oestrus (e.g. at start of mating, 0.19±0.06) or achieving pregnancy (0.17±0.05). There was, however, a significant interaction between breed and year ($P<0.01$), the largest interaction effect being for Blond d'Aquitaine x Angus heifers whose pregnancy rates were more severely reduced by the drought (1981-born heifers).

The Angus and Hereford breed comparison at Waikite was obtained from the AS1 and HS1 lines, which had been subject to similar selection practices since 1971. No difference between them was significant (Table 1).

Effects of selection

When the control line (AC0) was compared with the 2 Angus selection lines (AS1 and AS2), there was no effect of selection on age at puberty but weight at puberty was 11% greater (24±5 kg) in the AS1 than in the AC0 line as the result of a direct selection response of 28±3 kg (13%) in October weight. There were small, non-significant, increases in the proportion of AS1 and AS2 heifers in oestrus at fixed time, compared with AC0.

Environmental Factors

Birth date

Regressions of oestrus age and oestrus weight on birth date (/d later) were negative ($P<0.01$) at 2 locations (Flock House and Waikite) (b_{age} = -0.7 d and b_{weight} = -0.6 kg), but positive at Waikeria (b_{age} = 0.7 d ($P<0.01$) and b_{weight} = 0.03 kg, n.s.)). At Goudies there was significant heterogeneity of the regression slopes across years ($P<0.05$), e.g. ranging from 0.66±0.29 to -0.40±0.31 d of oestrus age/d born later.

All regressions of the proportion showing oestrus (end of September or start of mating) on birth date were negative, averaging -0.0081/d ($P<0.01$). Because oestrus tended to occur earlier at Waikeria than at other locations, regressions on birth date at Waikeria were also computed for the proportions showing

TABLE 2 Effect of a drought season during puberty on ages and weights at puberty at 2 locations.

	Year born	No. of heifers	Puberty age (days)	Puberty weight (kg)	Live weight (kg) June	Live weight (kg) Oct or Nov	Weight gain (kg)	Proportion Oestrous (1)	Proportion Oestrous (2)	Proportion Oestrous (3)	Proportion Pregnant
Goudies											
Drought year	1982	278	404	241	169	254	85	0.17	0.47	0.71	0.86
Next year	1983	269	378	242	193	282	89	0.37	0.57	0.74	0.80
Standard error of difference			6	4	2	3	1	0.04	0.05	0.04	0.04
Flock House											
Drought year	1981	92	375	255	224	254	30	0.22	0.37	—	0.57
Next year	1982	125	351	241	227	295	68	0.70	0.82	—	0.92
Standard error of difference			8	4	3	3	2	0.06	0.06	—	0.04

1 showing oestrus by the end of September
2 showing oestrus by the start of mating
3 showing oestrus by mid-December (2 to 3 weeks after (2))

oestrus by July 1 (-0.0070/d, $P<0.01$) and by August 1 (-0.0107/d, $P<0.01$).

Regressions of the proportion of heifers pregnant on birth date were non-significant at Goudies and Waikite, but significantly negative at Flock House and Waikeria (-0.005 and -0.003/d, respectively, both $P<0.01$).

Age of dam

Age of dam did not affect pregnancy rate. For all other traits the direction of effects due to age of dam was the same at each location, although not always significant. For example, at Waikeria, the differences between the performance of heifers out of 5- *v* 2-year-old dams were: -24±6 d and 8±3 kg (age and weight at puberty) and 0.12±0.05 (proportion oestrus by the end of September).

Year effects

There were, in general, significant year effects on performance, and it was decided to concentrate attention on drought year effects (Table 2) on 1981-born heifers at Flock House and 1982-born heifers at the other locations, especially Goudies. Different patterns were evident at Goudies and Flock House, probably because the drought occurred earlier in the season at Goudies than at Flock House (see live weights and gains from June to October/November). The net result (relative to the following year) was an increase in pubertal age at both locations (26±6 and 24±8 d, respectively), and increase in weight at puberty at Flock House only (14±4 kg), significant effects on early oestrus at both locations (-0.20±0.04 and -0.48±0.06, respectively), and on later oestrus (-0.10±0.05 and -0.45±0.06 respectively), but on pregnancy rate at Flock House only (-0.35±0.05).

Location effects

There were large differences in Angus performance among locations. Birth dates differed for management reasons. It is not clear how much of the variation in pubertal traits and oestrus proportions was due to management and presumed differences in feed availability and how much was due to the dates and time period of oestrus recording. The range in proportions of Angus pregnant after 8 weeks of mating was narrow (0.73 to 0.83).

DISCUSSION

Genetic Factors

Angus and Hereford heifers did not differ in age or weight at puberty at Waikite. However at Goudies, Angus were slightly older (but not significantly) and heavier at puberty ($P<0.05$) than Herefords, in contrast to the opposite findings in American data by Laster *et al.* (1976) from a large sample of sires but only 126 heifers. Heterosis effects on puberty also differed between the American and Goudies data. While heterosis at Goudies appeared to be for a higher weight at puberty, and minimal difference in age, results in the American study showed heterosis for a younger age (19.5 days) but little effect on weight suggesting that there might be a different trigger for puberty in the 2 crossbreeding studies.

At Goudies, dairy crosses were younger than Angus at puberty, as was found also for Jersey-crosses in America: -49 days (Laster *et al.*; 1976). The mean of 258 kg at puberty at Whatawhata (Smeaton and Winn, 1981) was not very different from the value of 250 kg for the same Angus and Friesian-cross breed types at Goudies. In contrast, Dalton *et al.* (1980) found a mean of 202 kg for Friesian crosses; starting recording in late summer (during a reducing photoperiod) may have been significant in their study.

Weight selection at Waikite seemed to increase pubertal weight but not age. Falconer (1984) concluded from a long-term weight selection experiment with mice that females in the weight-selected line were heavier and younger at puberty than controls, whereas selected males were similar in age to (and therefore heavier than) the controls.

After adjustment for known environmental effects, the residual correlations between pubertal age and weight, obtained from 2 locations (Goudies and Flock House) were 0.70 and 0.47 respectively. Correlations between October/November ('yearling') weight and pubertal weight were 0.52 and 0.64; between yearling weight and heifer progeny rate they were 0.05 and 0.04. Preliminary estimates of paternal half-sib heritabilities from Goudies were 0.31±0.19 and 0.45±0.19 for pubertal age and weight, respectively. Published heritability estimates for pubertal age and weight, reviewed by Baker and Morris (1984), averaged 0.31 and 0.40, respectively, although a more recent large American study found higher heritability values of 0.61 and 0.70 respectively (MacNeil *et al.,* 1984).

In the present study the genetic correlation was 0.87 between pubertal age and pubertal weight, -0.37 between yearling weight and age at puberty and 0.22 between yearling weight and weight at puberty. For comparison the genetic correlation estimates reviewed by Baker and Morris (1984) were values of 0.52 between pubertal age and pubertal weight, and -0.29 between yearling weight and pubertal age. There were no estimates of the genetic correlation between yearling and pubertal weights. However, preliminary estimates at Trangie (New South Wales) are available for responses in heifer puberty to selection for or against weight gain from birth to the yearling stage (reviewed by Baker and Morris, 1984). Selection for increased yearling gain reduced age at puberty (-37 d) and increased weight at puberty (+26 kg), for a 21 kg increase in direct response. Corresponding changes in the 'down' selection line at Trangie were in the opposite direction. The recent American study (MacNeil *et al.,* 1984) found small genetic correlations: average daily gain with age at puberty 0.16; average daily gain with weight at puberty 0.07.

Environmental Factors

Heifers that were born later than average were consistently younger and lighter than average at puberty at Flock House and Waikite. Different results were found at Goudies and Waikeria. All locations had consistent birth date effects on proportions achieving oestrus in September or at the start of mating (younger heifers having less oestrous activity) but not necessarily on proportions pregnant.

Age of dam effects on all traits except pregnancy rate were reasonably consistent, with young dams having daughters which reached puberty when older but lighter than average, i.e. a different form of penalty from the birth date effect.

Effects of the drought season may have depended on timing: an early drought at Goudies (5 to 9 months of age) affected pubertal age but not weight, whereas a later drought at Flock House (9 to 13 months of age) affected both traits. These contrasts were reflected also in the data for the proportions oestrous and pregnant.

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