VARIATIONS IN AND RELATIONSHIPS BETWEEN REPRODUCTIVE PERFORMANCE AND GROWTH PARAMETERS IN YEARLING BEEF BULLS IN SINGLE-SIRE MATING AT PASTURE

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Yearling bull fertility, measured as pregnancy rate, percentage of calves born during the first 4 and 6 wk of calving and mean and median of calving date distribution, were studied in 109 single-sire breeding herds of two breed groups over a 10-yr period. The breed groups were Herefords bulls mated to purebred and crossbred Hereford cows, and Beef Synthetic bulls mated to Beef Synthetic cows. The bulls averaged 14 mo old at the start of breeding. The average bull-to-cow ratio was approximately 1:22, and the breeding season started on 1 July each year and extended for 60 d. Two out of 109 bulls (1.8%) were subfertile (less than 50% pregnancy of the herd). The Beef Synthetic, which had crossbred foundation, had significantly higher fertility, calved earlier, had smaller phenotypic variance, and lower year-to-year fluctuation in the reproductive traits than the Hereford. Variations in reproductive performances of bulls of the same breed group used in the same year were much larger than those among different years, the former comprised over 75% of phenotypic variance of the traits in the two breed groups. Relationships between fertility of bulls and their weight and growth parameters were negligible, but bull fertility tended ($P<0.10$) to improve with age. Bulls that were heavy at weaning, end of feedlot test and breeding settled their mates earlier during the breeding season.

Key words: Beef cattle, yearling bull, fertility

[Variations dans les rapports entre le rendement reproducteur et les paramètres de la croissance chez les bovins de boucherie d'un an au cours d'essais d'accouplement à un seul géniteur au paturage.]
Titre abrégé: Reproduction et croissance des bovins de boucherie.
Nous avons étudié la fertilité des taureaux d'un an évalués à partir du taux de gestation, du pourcentage de veaux nés au cours des quatre ou des six premières semaines de vêlage, et des valeurs moyennes et médianes de la date de vêlage chez 109 troupeaux de reproduction à un seul géniteur appartenant à deux groupes de races sur une période de dix ans. Les groupes de races étaient: (1) taureaux Hereford accouplés à des vaches Hereford de race ou croisées; (2) taureaux de race synthétique de boucherie accouplés à des vaches de race synthétique de boucherie. Au début de la période d'accouplement, les taureaux étaient âgés en moyenne de 14 mois. Le nombre de vaches accouplées par taureau s'élevait en moyenne à 22 et la saison d'accouplement commençait le 1[er] juillet de chaque année pour durer 60 jours. Deux des 109 taureaux étudiés (1,8%) étaient subfertiles (taux de gestation inférieur à 50% dans le troupeau). Les sujets de race synthétique de boucherie, issus de sujets croisés ont laissé voir une fertilité significativement plus élevée, un vêlage plus hâtif, un variance phénotypique moindre

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et une fluctuation moindre, d'une année à l'autre, des caractéristiques de la reproduction, comparativement aux sujets Hereford. Les variations observées dans le rendement reproducteur de taureaux du même groupe de race utilisés la même année étaient beaucoup plus grandes que celles observées entre des années différentes, les premières englobant plus de 75% de la variance phénotypique des caractéristiques dans les deux groupes de race. Les rapports entre la fertilité des taureaux d'une part et leur poids et leurs paramètres de croissance d'autre part étaient négligeables, mais la fertilité des taureaux avait tendance ($P<0,10$) à augmenter avec l'âge. Les vaches accouplées aux taureaux plus lourds au sevrage, à la fin des essais en parc d'engraissement et à l'accouplement ont commencé leur période de gestation plus tôt pendant la saison de reproduction.

Mots clés: Bovins de boucherie, taureaux d'un an, fertilité

Bull fertility is of great importance to the beef cattle industry as it has a large effect on net return per cow and efficiency of production. There is a large body of published research on the fertility of bulls in confinement, the majority of which is on dairy breeds. Much less information is available on natural fertility of yearling beef bulls used under range conditions. Breeding soundness evaluation techniques have been used in several studies to assess fertilizing capacity of a relatively large number of bulls (Hill et al. 1959; Maddox et al. 1959; Carroll et al. 1963; Elmore et al. 1975; Ruttle et al. 1983). Cost, time and facilities required have probably been the prohibitive factors in relating assessments of bull reproductive potential to actual breeding performance under natural breeding conditions at pasture using sufficient number of bulls. It is desirable to have an estimate of the degree of variation among beef bulls for fertility under natural mating at pasture, and to identify the nature and relative importance of factors which contribute to differences in fertility among bulls. Such information could be useful in managing breeding bulls and in selecting bulls with superior fertilizing potential.

The objectives of this study were to quantify year to year variation and individual bull differences in reproductive performance, and to study the relationships between natural service fertility and growth parameters in yearling bulls used for single-sire mating at pasture.

MATERIALS AND METHODS

Records on pregnancy rates and calving dates of 2452 cows of mixed ages mated to 109 yearling bulls in single-sire breeding herds were available for this study. Data were collected during a 10-yr period (from 1970 to 1979 inclusive) at the University of Alberta ranch, Kinsella, Alberta. Breeding herds were Hereford (HE) bulls mated to purebred and crossbred Hereford cows, and Beef Synthetic (SY) bulls mated to SY cows. The HE was a purebred population, and the Crossbred HE population was composed of crossbred beef breeds with at least ½ HE contribution. The SY was a composite predominantly of Carolais, Angus and Galloway breeding, which was established in 1960 (Berg et al. 1986). One SY bull was infertile, and one HE bull was subfertile (fertility = 18.8%). Data on these herds were not mixed with the others, but were handled separately.

Calves were born between April and early June each year and weaned in mid-October without having access to creep ration. Bull calves were placed on a 140-d feedlot growth performance test following a 3-wk postweaning adjustment period, and were fed ad libitum a ration of 64% barley, 21% oats, 10% pelleted dehydrated alfalfa hay and 5% protein-mineral-vitamin supplement. Bulls selected for breeding ranked highest for average of weaning weight and feedlot daily gain. Bulls were not evaluated for libido or semen characteristics, nor was any attention paid to their reproductive organs at the time of selection, apart from a routine inspection for general physical soundness. Selected bulls were turned onto pasture in late April as an adjustment for the breeding season beginning in July.

The breeding herds were maintained on range year round and depended on natural grazing except for 4-5 mo in the late fall and winter when supplementary feed was provided. The breeding season started around 1 July and continued for two calendar months each year. Breeding females included yearling heifers and cows ranging in age from 2 to over 10 yr, and were assigned to breeding herds at random within each breed group and age subclass. Consequently, differences among herds within breed-year for age and body weight were small. All yearling heifers were exposed to bulls, and open females were culled after a pregnancy test by rectal palpation in January. Females which failed to wean a calf were culled, thus 2-yr-old and older cows were nursing at the time of breeding. Average size of breeding herds was 20.0 (17–26) in Hereford and 24.1 (17–32) in Beef Synthetic.

Pregnancy rate (number of calves born, dead or alive, as a percentage of cows exposed to a bull), percentage of very early and early born calves (number of calves born during the first 4 and 6 wk of calving, respectively, as a percentage of total calves born), and mean and median of calving date distribution for the herds were considered as measures of bull fertility, and were analyzed by the method of weighted least-squares using the LSML-76 program (Harvey 1976). The numbers of cows exposed to a bull (for pregnancy rate) or the numbers of calves born (for the other traits) were used as weighting factors. The model of analysis included the effects of breed group of bull (fixed), year (random) and their interaction. Arcsine transformation of percentages of pregnancy rate and early born calves did not affect significance levels, and therefore untransformed data were subjected to the final analyses. In another analysis, which was performed within each breed group, among-years ($\delta^2 b$) and among-bulls within-year ($\delta^2 w$) components of variance were estimated. Variance of the observed year means ($\delta^2 m$) which is expected to be the sum of real year variance ($\delta^2 b$) and sampling variance ($\delta^2 s$) was computed for each trait. Sampling variance is expected to be $(1/k)\delta^2 w$, where k is the harmonic mean of the number of bulls per year (k was 4.18 and 6.48 in the HE and SY, respectively). These parameters were utilized to examine the relative contribution of the real year variance and sampling variance to the year to year variation of means of different traits. Variance of observed year means could be partly due to a trend over years and partly due to year-to-year fluctuations. In order to test the presence of any trend in means of each trait over years, the raw means within each breed group were regressed on year. Variances were compared using the F statistics. Residual correlation coefficients between the measures of reproductive performance and bulls' age and growth parameters (birth weight, weaning weight, preweaning average daily gain, end of feedlot weight, feedlot average daily gain, and body weight at the start of breeding season) were computed after removing the effects of breed group, year and their interaction.

RESULTS

The SY-sired herds had significantly higher fertility and calved earlier than the HE-sired herds (Table 1). Year differences were observed on all measures of bull fertility, except percentage of very early born calves. Superiority of the SY over HE was consistent among years for all traits studied, as breed group by year interaction was not significant for any of the traits.

Variation among bulls for fertility (even after ignoring the infertile and subfertile bulls) was large, as the pregnancy rates ranged from 55.0 to 95.8% in the HE and from 63.9 to 100% in the SY herds. Except for percent fertility in the HE, among-bulls within-year components of variance ($\delta^2 w$) comprised more than 75% of the total phenotypic variance of the reproductive traits in bulls in the two breed groups (Table 2). The variances of year means ($\delta^2 m$) for the traits studied are shown in Table 3. The among-year components of variance ($\delta^2 b$) were smaller, and mostly significantly so, than $\delta^2 m$s for all traits in both breed groups, and the differences between these two parameters is attributable to the sampling variance ($\delta^2 s$). Variances of year means ($\delta^2 m$) were close to $\delta^2 b + \delta^2 s$ for all traits in both populations (Table 3), showing that $\delta^2 m$ was largely accounted for by the true year variance ($\delta^2 b$) and the sampling variance ($\delta^2 s$). Except for percent fertility in both breed groups, and percent early born calves in the HE, $\delta^2 b$ was much smaller than $\delta^2 s$ for all the traits, shown by $100\delta^2 s/\delta^2 s$ in Table 3. The estimates of total phenotypic variance, $\delta^2 b$ and $\delta^2 m$ for most of the traits were larger in the HE than those in the SY, while the former breed group had smaller $\delta^2 w$ for all traits. The differences were, however, significant only for total phenotypic variance, $\delta^2 b$ and $\delta^2 m$ for percent fertility, and $\delta^2 b$ for percent early born calves.

The significant effect of year on the measures of bull fertility was primarily the result of year-to-year fluctuations rather than any trend. All measures of bull fertility stayed

Table 1. Least-squares means and standard errors of pregnancy rate and measures of calving date by breed group

Traits	Overall mean	Hereford	Beef Synthetic
Number of herds	107	42	65
Number of cows	2409	840	1569
Pregnancy rate (%)	84.1±0.8	82.3±1.4*a*	85.9±1.0*b*
Early born calves (%)†			
First 4 wk	57.0±1.5	54.6±2.5	59.5±1.8
First 6 wk	78.7±1.1	76.0±1.7*a*	81.4±1.2*b*
Calving date‡			
Mean	29.5±0.5	30.7±0.8*a*	28.4±0.6*b*
Median	25.3±0.6	25.7±0.9	24.8±0.7

†Number of calves born in each period as percentage of total calves born.
‡Day 1 is the first day of calving within each year.
*a,b*Means followed by different letters are different at $P<0.05$.

Table 2. Among years (δ^2b) and among-bulls within-year (δ^2w) components of variance as percentage of total phenotypic variance (δ^2P) for pregnancy rate and measures of calving date

	Hereford			Beef Synthetic		
Traits	δ^2b/δ^2p (%)	δ^2w/δ^2p (%)	δ^2p	δ^2b/δ^2p (%)	δ^2w/δ^2p (%)	δ^2p
Pregnancy rate, (%)	60.4	39.6	126.8	14.5	85.5	74.3
Early born calves, (%)†						
First 4 wk	8.9	91.1	255.1	2.7	97.3	241.0
First 6 wk	24.6	75.4	127.4	3.2	96.8	120.9
Calving date‡						
Mean	13.5	86.5	34.0	7.3	92.7	27.5
Median	7.5	92.5	31.3	6.4	93.6	33.1

†Number of calves born in each period as percentage of total calves born.
‡Day 1 is the first day of calving within each year.

Table 3. Variance of observed year means (δ^2m) and sampling variance (δ^2s) of pregnancy rate and measures of calving date

	Hereford				Beef Synthetic			
Traits	δ^2m	δ^2s	$\delta^2b+\delta^2s$	$100\delta^2b/\delta^2s$	δ^2m	δ^2s	$\delta^2b+\delta^2s$	$100\delta^2b/\delta^2s$
Pregnancy rate (%)	85.9	12.0	88.6	637.6	22.2	9.8	20.6	109.9
Early born calves (%)								
First 4 wk	84.6	55.6	78.3	40.9	48.5	36.2	42.7	17.9
First 6 wk	58.9	23.0	54.3	136.3	19.7	18.0	22.0	21.7
Calving date								
Mean	14.4	7.0	11.6	65.5	6.4	3.9	6.0	51.3
Median	12.7	6.9	9.3	33.8	7.5	4.8	6.9	43.9

δ^2b: among-year component of variance.

unchanged over the 10-yr period in the SY, while calvings tended to delay from 1970 to 1979 in the HE, as shown by negative regression coefficient of percent very early born calves ($P=0.09$) and positive regression coefficient ($P=0.06$) of median calving date distribution on years (Table 4).

The SY bulls outperformed the HE for all growth traits, but the mean age of bulls was the same in the two breed groups (Table 5). Residual correlations indicated no relationship between pregnancy rate and growth parameters, but bull fertility tended ($P<0.10$) to improve with age (Table 6). Bulls which

Table 4. Regression coefficients (*b*) of pregnancy rate and measures of calving date on years

Traits	Hereford		Beef Synthetic	
	b±SE	$\%R^2$	b±SE	$\%R^2$
Pregnancy rate (%)	0.84±0.61	4.5	0.14±0.39	0.2
Early born calves (%)				
First 4 wk	−1.49±0.87*a*	6.7	0.76±0.70	1.8
First 6 wk	−.20±0.64	0.2	0.67±0.49	2.8
Calving date				
Mean	0.35±0.33	2.9	−.22±0.24	1.3
Median	0.60±0.30*a*	8.7	−.17±0.26	0.7

a Different from 0 at $P<0.10$.

Table 5. Least-squares means and standard errors of body weights, gains and age of bulls by breed group

Traits	Overall mean	Hereford	Beef Synthetic
Birth weight (kg)	38.0±0.5	35.5±0.8*a*	40.5±0.6*b*
Weaning weight (kg)	199±3	182±4*a*	217±3*b*
Preweaning daily gain (kg)	1.05±0.01	0.95±0.02*a*	1.14±0.01*b*
Feedlot daily gain (kg)	1.61±0.01	1.52±0.03*a*	1.71±0.02*b*
End of test weight (kg)	428±3	399±5*a*	456±3*b*
Weight at breeding (kg)	440±4	412±6*a*	468±5*b*
Age at breeding (d)	427±2	426±3	428±2

a,b Means followed by different letters are significantly different ($P<0.05$).

Table 6. Residual correlation coefficients of measures of bull fertility with growth parameters and age

Growth parameters	Pregnancy rate (%)	Early born calves (%)		Calving date	
		First 4 wk	First 6 wk	Mean	Median
Birth weight (kg)	0.01	0.28**	0.14	−0.17*a*	−0.22*
Weaning weight (kg)	0.03	0.28**	0.17*a*	−0.21*	−0.16
Preweaning daily gain (kg)	−0.04	0.22*	0.12	−0.10	−0.09
Feedlot daily gain (kg)	0.00	0.06	0.06	−0.03	0.05
End of test weight (kg)	0.03	0.24*	0.17*a*	−0.19*a*	−0.09
Body weight at breeding (kg)	0.04	0.22*	0.18*a*	−0.17*a*	−0.07
Age at breeding (d)	0.17*a*	0.03	0.06	−0.11	−0.04

a,*,**Significant at $P<0.10$, $P<0.05$, and $P<0.01$, respectively.

were heavier at birth, weaning and at the end of feedlot test, impregnated their mates earlier in the breeding season, but the rate of pre- or postweaning gain was not generally related to the measures of calving date. Percentage of very early born calves was positively related to all growth traits ($P<0.05$), except feedlot daily gain, and the magnitude of the correlation coefficients was smaller for percent early born calves.

DISCUSSION

Although reproductive traits were not considered in selecting the bulls for breeding, the number of bulls which showed severe fertility problems was relatively small (one infertile and one subfertile out of 109 bulls). This would be an estimate of the risk involved when untested yearling bulls are used in single-sire mating of short duration under commercial conditions. Assuming that bulls which are classified as unsatisfactory breeders based on the breeding soundness evaluation tests (Society for Theriogenology 1976) are expected to have severe fertility problems, the proportion of such bulls in this study was much smaller than the percentage (5–11%) of the bulls which have been classified as unsatisfactory potential breeders in several studies (Hill et al. 1959; Maddox et al. 1959; Carroll et al. 1963; Elmore et al. 1975; Ruttle et al. 1983). The observed difference may suggest that either the above assumption is not true, or that breed and environmental factors were responsible for the difference. There is also the possibility that bulls selected on the basis of high growth rate would have less chance of encountering severe fertility problems.

Bull fertility, as measured in this study, is the end result of many complex and interacting factors, such as bull's physical soundness, libido, seminal traits and mating ability, as well as females' reproductive potential and embryo survival. It is hardly possible to assess the contribution of any particular factor to the total variation in reproductive performance of beef bulls under range conditions. It was, however, possible to demonstrate on a quantitative basis, and insofar as the data permitted, the relative magnitude of some sources of variation in reproductive traits of bulls. The finding that among-bull differences within each year comprised more than 75% of the total phenotypic variance of the measures of bull fertility is in agreement with other reports (Seebeck 1973; Rupp et al. 1977; Chenoweth 1978; Neville et al. 1979; Smith et al. 1981; Lunstra and Laster 1982; Bamualim et al. 1984; Makarechian and Farid 1985; Makarechian et al. 1985). These investigators, using relatively small numbers of bulls, reported the existence of a considerable degree of variation in fertility among individual beef bulls, and that the differences were primarily the characteristics of individual bulls rather than their age, bull-to-cow ratio or mating systems. The ratio $100\delta^2 b/\delta^2 s$ measures the relative importance of real year variance and sampling variance contributed to the variance of year means. The results suggest that year-to-year fluctuations, particularly for the measures of early calving, were due to the small number of bulls, and contribution of true year variance was relatively small.

The data covered a relatively long period of time with considerable year-to-year variation in such factors as climatic conditions and vegetation, as well as possible changes in genetic structure of the populations. The lack of any direct selection for fertility traits in bulls, low heritability of reproductive traits, and a small number of generation turnovers in females may suggest that change in the genetic structure of the populations for reproductive traits could not have been considerable. This was supported by the absence of any time trend for the reproductive traits (Table 4). Explanations for the large variation in reproductive traits among bulls within each year should thus be sought in the microenvironment under which bulls were raised and mated. Weak associations between the growth parameters and percent fertility of bulls may indicate that the elements of microenvironment, such as nutrition, subclinical illness, etc., which influence growth parameters, were not among the critical factors influencing bull fertility. In fact, any factor with a depressing effect on the growth rate of a growing bull could not have been responsible for variation between bulls for fertility as growth rate was the main criterion in selecting the bulls.

The absence of a strong relationship between growth parameters and percent fertility is in general agreement with the reports of other investigators who used different components of bull fertility such as libido score, serving capacity score, semen quality and breeding soundness scores (Ologun et al. 1978; Pape et al. 1982; Hughes et al. 1985). Makarechian et al. (1985) reported a positive and significant relationship between percent fertility of yearling bulls and their feedlot average daily gain and yearling weight, but not with preweaning average daily gain or body weight at mating. Positive and significant correlation coefficients between percent very early born calives and growth parameters suggested that bulls with heavier body weights from birth to breeding were more likely to settle their mates earlier in the breeding season compared with the lighter ones. The bulls used in this study might be considered as unique because they were selected on the basis of their growth parameters alone, and therefore the sample had a narrow range for growth traits. This could be a factor for lowering the magnitude of correlation coefficients between reproductive and growth traits in this sample.

The percentage of very early born calves had the largest total phenotypic variance and the largest δ^2w amongst all the traits in the two populations, followed by percent early born calves and percent fertility. Breed group and year differences were significant for percent early born, but not for percent very early born calves. This was mainly due to the fact that δ^2w for the percentage of calves born during the first 4 wk of calving was large, and its magnitude was cut almost in half by the 6th week of calving in both breed groups. These findings imply that in those herds in which calving started later in the season, the delay was compensated to a large extent during the 5th and 6th weeks of calving and vice versa. The simple correlation coefficient between percentages of calves born during the first 4 wk of calving and those born during the 5th and 6th weeks of calving was -0.71 ($P<0.01$) in both breed groups. It may be concluded that bulls were much different in initiating their sexual activity during the breeding season. It is probable that mating ability has a learned component which largely affects the performance of yearling and inexperienced bulls, particularly during the first few weeks of breeding, and such a component can be influenced by rearing and management systems (McFarlane 1974; Anderson and Zenchak 1976; Zenchak and Anderson 1980). The bulls used in the present study were managed similarly, but not identically, as they were in different pens in feedlot within each year, which could be one of the reasons for the observed differences among them. Furthermore, genetic differences between bulls for the components of reproductive potential such as libido and seminal traits, and the effect of environmental factors on these traits could not be ruled out. However, such factors are expected to affect percent fertility as much as they affect percent early born calves.

The superiority of SY-sired herds over HE-sired herds, which was consistent with a previous report (Makarechian et al. 1985), could have been due to the combined influence of both bulls and cows. The findings that total phenotypic variance, δ^2b and δ^2m of percent fertility, was larger in the HE than in the SY indicated that year-to-year fluctuation was larger in the former than that in the latter breed group. The main difference between the two populations was that the SY was genetically a more heterogenous population than the purebred HE. Genetic uniformity could allow populations to achieve closer adaptation to their immediate environment while reducing their flexibility in a variable environment (Allard et al. 1968; Mackay 1980). This might partly explain the large year-to-year variation of the HE population. The large degree of variability among bulls within year, measured by δ^2w, emphasizes the need for methods to screen the bulls for fertility prior to use. It seems, however, that one method to reduce year-to-year variation in reproductive traits would be to utilize breeds with a large degree of genetic heterogeneity (crossbreds).

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