Genetic Influences on Reproductive Performance of Two-Year-Old Beef Females

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Two important factors that influence the reproductive efficiency of two-yr-old heifers are age at puberty and calving difficulty. Most heifers have the potential to reach puberty and breed satisfactorily at yearling ages if provided adequate nutrition and management. However, the cost of doing so may vary greatly among breeds and among heifers within a breed. Heifers with the inherent ability to reach puberty at early ages may reach puberty and breed at less cost than heifers with later inherent age at puberty. Calving difficulty influences the economics of the cow herd through calf losses, increased labor or veterinary costs, poorer subsequent reproductive efficiency of the dam and occasional cow losses. Thus, calving ease is an important economic trait.

This discussion presents an overview of the genetic influences of age at puberty and calving difficulty on reproductive performance of young beef females.

Age at Puberty and Reproductive Tract Score - Since age at puberty is difficult to measure directly, a method for evaluating the reproductive tract of yearling heifers has been developed at Colorado State University (Anderson et al., 1990) and is described in table 1. The ovaries and uterus of heifers are examined by rectal palpation and assigned a score of 1 through 5. A heifer scoring 1 has a small, immature tract and is definitely not cycling and a heifer scoring 5 has a palpable corpus luteum and is cycling. This examination is performed prior to the breeding season. If taken 30 to 60 d before the breeding season, it can serve as a check on the nutritional program. Then, according to the resultant scores, the ration or the beginning of the breeding season can be adjusted.

Heritability estimates for age at puberty (AP) are relatively high (table 2), and average about 50% which is similar to scrotal circumference in yearling bulls. The heritability estimate for reproductive tract score (RTS) is somewhat lower as expected since the measure is less precise and the distribution of RTSs depends upon when the heifers are examined. If RTS is to be used as a selection tool, scoring should be done when about 25 to 50% of the heifers are thought to be cycling.

Relationship of AP and RTS to Growth - Estimates of genetic, environmental and phenotypic correlations of AP and RTS with various growth traits are listed in table 3. These estimates are from Colorado data. The genetic correlations of AP and RTS with growth traits tend to be similar to those between scrotal circumference and growth traits in yearling bulls. The negative correlations with AP (favorable) indicate that heifers growing more rapidly from a genetic standpoint reach puberty earlier. Positive correlations are favorable for RTS with measures of growth. Heifers in these studies were raised under limited feed resources from weaning until breeding. Other studies have reported a positive genetic correlation between age and weight at puberty. Laster et al. (1979), Arije and Wiltbank (1971) and Smith et al. (1976) reported values of .52, .36 and .67 indicating that, genetically, heifers reaching puberty at later ages were also heavier, or vice versa.

There also may be a seasonal effect (photoperiod) that contributes to the interpretation of the correlation. King et al. (1983) reported that although heifers born later in the calving season reached puberty at an earlier age, heifers born earlier in the calving season reached puberty at an earlier date the following year. The same phenomenon was observed in Colorado studies.

Relationship of AP and RTS to Subsequent Productivity - Correlations between line of breeding means of AP with reproductive and productivity traits through four lactations are presented in table 4.

The correlations among line of sire means may indicate a genetic relationship. These correlations indicate that heifers from lines with early puberty also tended to conceive earlier each year through four lactations, except for the third lactation. Also, they weaned heavier calves and had high accumulative most probable producing ability (MPPA) values, presumably through higher milk production.

This favorable relationship of earlier age at puberty with higher milk production and reproduction has also been observed from correlations among breed means from other studies. Laster et al. (1979) reported the following correlations among breed means: AP with percent calving the first 25 d, -.75; AP with pregnancy percent, -.42; and AP with milk production, -.88; indicating that earlier age at puberty resulted in earlier and more pregnancies and greater milk production on a between breed basis. Doornbos et al. (1983) reported a residual correlation of -.40 between AP and percent pregnant.

The relationship of reproductive tract score taken 30 d before the start of the breeding season and pregnancy rate is shown in table 5. An increase in both synchronized pregnancy rate and breeding season pregnancy rate was seen for the heifers with higher reproductive tract scores. In addition, of heifers that did conceive, heifers with reproductive tract scores of 1 and 2 conceived later in the breeding season than those with higher scores.

Calving Ease - The data used in analyzing calving ease is from a scoring system recommended by the Beef Improvement Federation (1986) shown in table 6. Scores of 1 through 4 are used in the analyses of calving ease data and scores of 5 are omitted. Usually, only calving ease data from first calf heifers is analyzed since that is where most problems exist and because breeders are interested in selecting specific sires to breed to heifers.

The genetic influence of sires on calving ease of their progeny can be divided into a direct component and a component due to maternal effects (figure 1). The direct calving ease expected progeny difference (EPD) value is the average calving ease score difference we expect on progeny by a sire. This difference is usually converted into a ratio with values over 100 indicating superior calving ease and values below 100 indicating more calving difficulty. Thus, different sires' EPD values can be compared as to the ease of calving expected on their progeny. The direct EPD value is due primarily to differences in progeny birth weight, gestation length and shape of calf associated with sire effects.

The maternal calving ease EPD for sires is determined by genes passed on by the sire to his daughters that affect their pelvic measures, uterine environment, hormonal control, etc. which in turn affect calving ease. This value is usually not reported since one is interested in the total maternal EPD of the sire. The total maternal EPD value of a sire is due to genes passed on from the sire to his daughters for both direct and maternal effects. This total maternal EPD value is the calving ease score difference we expect daughters of a sire (maternal grandsire of calves) to experience during parturition; in other words, how easily a sire's daughters give birth. It is computed as one-half the direct EPD plus all of the maternal EPD. This value is also converted into a ratio before reporting.

The interpretation of EPDs of dams is exactly the same as that for sires. However, the dam's contribution to maternally affected traits differs from the contribution of sires to the actual values expected in the progeny (figure 2).

The dam contributes to calving ease of her progeny both through her direct and her maternal EPD values. The direct EPD value is interpreted the same as a sire's and is determined by genes passed on to the progeny for birth weight, calf shape, and gestation length (genotype of calf).

In addition, she contributes to the calving ease of her progeny based on her own genetic makeup for pelvic area, uterine environment (size, nourishment, etc.) and hormonal control or calving behavior. In this maternal component, she expresses her full breeding value which is twice her maternal EPD value. The EPD value is by definition, one-half the breeding value of an individual.

Heritability estimates for calving ease and traits affecting calving ease are listed in table 7. These values were taken from breed association sire summaries.

Considerable differences exist among heritability estimates for calving ease direct and maternal. Apparently the genetic influence on this trait varies widely among breeds. Birth weight is the most important factor affecting direct calving ease. Heritability estimates from breed association data indicate that this trait is fairly highly heritable.

The genetic makeup of the calf plays an important role in triggering parturition and therefore gestation length. Apparently, gestation length is highly heritable. However, the trait does not show much total variation and therefore large changes are not expected through selection.

Genetic correlation estimates among factors affecting calving ease and correlations with calving ease from breed association data are listed in table 8. The genetic relationship between birth weight and calving ease is fairly high (.40 to .60) indicating that as birth weight increases problems with calving increase. Genetic relationships between birth weight and gestation length are lower (.16 to .26) as are those between gestation length and calving ease (.20 to .26).

Pelvic Measures - Recently, there has been considerable interest in and some research on pelvic measures as related to improving calving ease. Most studies have worked with yearling heifers and in some cases, yearling bulls. As with most anatomical measures that can be measured accurately, these studies have shown pelvic measures to be highly heritable with fairly large breed differences in size and shape.

Heritability estimates for pelvic measures obtained from the Colorado study (Green et al., 1988a) with cows, heifers and yearling bulls, both on an age adjusted and on a weight adjusted basis are listed in table 9.

Heritability estimates were generally high except for width measures for yearling heifers and yearling bulls. Heritability estimates for pelvic height were consistently high. Interestingly, heritability estimates from data adjusted for differences in body weight were only slightly lower than those adjusted for age differences. This suggests considerable genetic variation in pelvic dimensions not associated with weight differences. Analyses using hip height instead of body weight yielded similar results. Thus, it appears that taking pelvic measures instead of relying solely on weight and skeletal size is justified. These estimates of pelvic measures are somewhat higher than other estimates in the literature.

The estimates of genetic correlations between height and width were moderate with .29 in the cow analysis and .23 in the heifer analysis. Height was more highly genetically correlated with area (HxW) than was width since it is a somewhat larger dimension. Genetic correlation estimates of height with area were .86 and .93 in the cow and heifer analyses whereas corresponding values between width and area were .73 and .58.

Estimates of genetic correlations between pelvic measures in yearling bulls and pelvic measures of half-sibling yearling heifers were also obtained and are listed in table 10.

Most genetic progress is made through sire selection and therefore a measure in yearling bulls which would predict measures in female offspring would be useful. Pelvic height in yearling bulls appears to be such a measure as it appears to be highly correlated with female height, width and area on both an age or weight adjusted basis. Selection for increased male pelvic height should result in correlated increases in pelvic dimensions of female offspring. If female pelvic dimensions are increased and birth weights of offspring are held constant, it seems logical to expect improvement in maternal calving ease.

Summary - The most important step in producing reproductively efficient young females is sire selection. Sires excelling in maternal and reproductive traits including optimum cow size, optimum milk level, large scrotal circumference (early puberty) and large pelvic measures (maternal calving ease) should be used to produce the heifers from which to select. The use of expected progeny difference values should aid greatly in locating bulls excelling in these maternal characteristics.

Age at puberty appears to be highly heritable and favorably related to growth traits and subsequent measures of reproduction and production. Reproductive tract score is a measure of age at puberty and is useful in predicting pregnancy rate to synchronized breeding, pregnancy rate at the end of the breeding season and conception date. Pelvic measures are highly heritable and increasing pelvic area should aid in improving maternal calving ease.

Reproductive tract scores and pelvic measures can be taken in conjunction with collection of yearling weights and general processing as part of the yearling heifer evaluation and health program. Using selection to improve reproductive traits should result in a permanent, low cost method of improving reproductive efficiency.

Pelvic measures, indicators of maternal calving ease, can be obtained on yearling bulls during the breeding soundness examination and on yearling heifers when reproductive tract scores are obtained. Increasing pelvic area should improve the maternal calving ease of the cow herd.

Expected progeny difference values on some of these traits are currently available in the U.S. and others are forthcoming. These EPD values, along with individual performance information should aid producers in improving overall reproductive efficiency.

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Table 1. Description of Reproductive Tract Score					
		Ovaries			
		Approximate size			
Reproductive tract score	**Uterine horns**	**Length (mm)**	**Height (mm)**	**Width (mm)**	**Follicle diameter**
1	Immature < 20 mm diameter - no tone	15	10	8	<8 mm
2	20 to 25 mm diameter - no tone	18	12	10	8 mm
3	25 to 30 mm diameter - good tone	30	16	10	9 to 10 mm
4	32 to 35 mm diameter - good tone - erect	32	18	12	>10 mm corpus luteum possible
5	> 35 mm diameter	>32	20	12	>10 mm corpus luteum present

Table 2. Heritability Estimates for Age at Puberty and Reproductive Tract Score	
Source	**Heritability**
Age at Puberty	
Arije (1971)	.20
Laster et al. (1979)	.41
Werre (1980)	.67
King et al. (1983)	.48
Smith et al. (1976)	.64
Lunstra (1982)	.41
Reproductive Tract Score	
Anderson et al. (1990)	.32

Table 3. Genetic (G), Environmental (E) and Phenotypic (P) Correlations				
Source		**Birth wt.**	**Weaning wt.**	**Yearling wt.**
Age at Puberty				
Werre (1980)	G	-.16	-.31	-.25
	E	.03	-.04	.06
	P	-.08	-.13	-.03
Smith et al. (1989)	G	.58	-.04	-.14
	E	-.10	-.19	-.19
	P	.02	-.17	-.16
Reproductive Tract Score				
Anderson et al. (1990)	G	-.37	.20	.31
	E	.07	.60	.94
	P	-.02	.41	.44

Table 4. Correlation of Age at Puberty with Productivity Traits[ab]

	1st lactation			**2nd lactation**			**3rd lactation**			**4th lactation**		
	HCC	AWWR	MPPA	HCC	AWWR	MPPA	HCC	AWWR	MPPA	HCC	AWWR	MPPA
Age at Puberty	.54	-.65	-.62	.34	-.11	-.38	-.06	-.24	-.10	.47	-.11	-.25

[a] From Werre and Brinks (1986)
[b] HCC = Heat cycles of conception (1 = early, 3 = late), AWWR = adjusted 205 d weaning weight ratio, MPPA = most probable producing ability

Table 5. Reproductive Tract Score Relationship with Pregnancy Rate and Average Conception Date					
Reproductive tract score	No.	Pregnant first 5 d (%)[a]	Pregnant breeding season (%)[b]	No.	Average conception date[c]
1	13	0	38	4	35
2	69	23	61	42	25
3	185	32	70	137	17
4	58	55	93	54	15
5	293	54	85	248	13

[a] Heifers were synchronized with either Synchro-Mate B or MGA-$PGF_{2\alpha}$.
[b] Breeding season was approximately 60 d long.
[c] Average conception date is the average d into the breeding season that conception occurred.

Table 6. Calving Ease Scoring System	
Score	
1	No difficulty, no assistance
2	Minor difficulty, some assistance
3	Major difficulty, usually mechanical assistance
4	Cesarean section or other surgery
5	Abnormal presentation

Table 7. Heritability Estimates for Traits Affecting Calving Ease (CE)				
Source	Direct CE	Maternal CE	Birth weight	Gestation length
Simmental	.07	.07		.37
Male			.41	
Female			.48	
Polled Hereford	.37	.10	.56	.64
Gelbvieh	.47	.60	.56	
Red Angus			.46	
Charolais			.52	

Table 8. Genetic Correlations with Calving Ease		
Trait	**Gestation length**	**Calving ease**
Birth weight		
Simmental	.26	.40
Gelbvieh	.16	.45
Polled Hereford		.60
Gestation length		
Simmental		.26
Gelbvieh		.20

Table 9. Heritability Estimates for Pelvic Measures[a]			
Source	**Height**	**Width**	**Area**
Age adjusted			
Cows	.79	.78	.92
Heifers	.83	.19	.56
Bulls	.45	.16	.40
Weight adjusted			
Cows	.76	.83	.91
Heifers	.74	.09	.47

[a] From Green et al. (1988a)

Table 10. Genetic Correlation Estimates between Male and Female Pelvic Measures[a]			
Female	**Male**		
	Height	Width	Area
Age adjusted	.74	.24	.50
Height	.78	.38	.62
Width	.83	.28	.60
Area			
Weight adjusted	.63	.36	.47
Height	.72	.51	.62
Width	.72	.49	.60
Area			

[a] From Green et al. (1988b)

Figure 1. Sire values for direct, maternal and total maternal calving ease EPD that affect progeny calving ease (CE).

Figure 2. Dam EPD values contributing to progeny calving ease (CE).