Evaluation of Selection Practices in Three Lines of Beef Cattle

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Summary

Selection practices in three synthetic lines of beef cattle were evaluated based on data collected over 12 to 13 years. Sires from the Jersey, Angus and Simmental breeds were mated to three lines of foundation crossbred dams to produce first generation progeny. Subsequent calves were produced mating crossbred parents of the same generation. Crossbred sires were selected based on an index that included hip height and weight at weaning. At Rhodes, a total of 2.84 to 3.07 generations of selection have been carried out. This provided a mean generation interval of 4.33, 4.23 and 4.58 years in small, medium and large lines, respectively. At McNay, the corresponding generation interval values were 4.15 years for small and medium lines and 5.29 years for the large. The mean weighted sire selection differential for the index in the small line was 1.28 σ/generation. In the medium cattle these values were -.57 σ/generation (Rhodes) and -.36 σ/generation (McNay). For the large synthetic cattle the index differential ranged from .71 σ/generation at McNay to .92 σ/generation at Rhodes. Of the total mean parental selection differential, sire contribution ranged from 86% to 95%. Selection differential values for components of the index indicated that the index equations often favored weaning weight, and this was very pronounced in the medium line. Regardless of the line, selection criteria have been strictly followed. However, all the maximum potential sires have not been utilized.

Introduction

The importance of frame size on the efficiency of beef production has long been documented. However, choice of the best size for a particular production condition depends on the net efficiency of the system, including biological, management, available resources and economic considerations. An equally important issue in the use of size differences for better efficiency is a thorough understanding of the genetic aspects of size-line formation. There is huge variability in mature size both within and between breeds of beef cattle. This represents a wide opportunity for making rational use of this characteristics through selection and crossbreeding. The objective of this analysis was to describe selection practices in three synthetic lines of beef cattle under two management conditions.

Materials and Methods

Source of data

Data used in the study came from a breeding project at Iowa State University. The project was designed to produce three synthetic lines of beef cattle differing in mature size and to study management-size interactions.

Foundation dams were from a previous dairy-beef crossbreeding experiment and had a beef breed composition of 75% and 72% at Rhodes and McNay, respectively (Northcutt, 1990). At the beginning of the project cows were assigned to three size groups (small, medium and large) based on their breed composition and hip height within the breed composition.

Sires from the Jersey, Angus and Simmental breeds were mated to the foundation cows to produce first-generation calves. Assignment of purebred sires to the respective dam lines was made based on their mature frame sizes. In the small line, first-generation calves were sired by small Jersey and small Angus. First generation progeny in the medium group were from large Jersey, medium Angus and small Simmental sires. The large line used large Angus and Simmental sires. In all lines subsequent generation calves were produced from matings of crossbred parents of the same generation.

In terms of breed composition, the objective was to produce synthetic cattle definable by the percentages of Jersey, Angus and Simmental breeds. Purebred sire contributions to the synthetic lines were:

Small : 1/4 Jersey, 1/4 Angus
Medium : 1/8 Jersey, 1/4 Angus and 1/8 Simmental
Large : 1/4 Angus, 1/4 Simmental

In the remaining half, the composition of synthetic calves was determined by the breed composition of foundation dams. Crossbred sires were selected on the basis of an index (IDX) that included weight and hip height at weaning. Index equations used in the respective lines were:

Small: $(W - \bar{W}) - 5(H - \bar{H})$
Medium : $|(W - \bar{W})| - 5\,|(H - \bar{H})|$
Large: $(W - \bar{W}) + 5(H - \bar{H})$

where,

W = adjusted WWT
H = adjusted WHT
$\bar{W}$ = mean line-location WWT
$\bar{H}$ = mean line-location WHT

Index equations were designed to increase weight in both the small and large lines while decreasing hip height in the small line and increasing it in the large line. In the medium line the index equation was designed to produce cattle to serve as controls for general size.

The three synthetic lines were replicated at two Iowa State University beef research farms (Rhodes and McNay). At Rhodes breeding took place in June and July with calving the following spring. Calves were weaned at approximately 200 days of age. Mating at McNay was carried out in November and December with fall-calving, and weaning was at age 45 days. The practice at McNay was followed until 1986. Starting in 1988 dams were bred to calve in spring. A detailed account of management practice for these two farms is given elsewhere (Buttram and Willham, 1989).

Traits included in this analysis were birth weight (BWT), birth hip height (BHT), weaning weight (WWT), weaning hip height (WHT), preweaning daily weight gain (ADG) and preweaning daily gain in hip height (ADH), and covers the years 1978-1990.

Traits were adjusted for age of dam effect using additive age adjustment factors.

Selection parameters were computed from data expressed in standard deviation units by dividing an individual calf's record by the line-location standard deviation of the respective traits. No adjustment was made for inbreeding and breed composition of a calf.

Generations and amount of selection applied

The generation coefficient was calculated according to Brinks et al. (1961).

$$GC = (GC_s + GC_d)/2 + 1$$

where,

GC = generation coefficient of a calf,

GC_s = generation coefficient of the sire,

GC_d = generation coefficient of the dam.

Numbers of generations of selection were then computed as one minus GC. Foundation parents were assigned a generation coefficient of zero.

Selection pressure applied was evaluated based on selection differentials per generation and cumulative selection differential. Selection differential values for selected sires and of all dams were calculated on a generation basis by averaging individual deviations with and without applying weight. Weight applied to a given sire deviation is meant to account for its contribution to the next generation. Cumulative selection differential for overlapping generations was calculated according to the method outlined by Newman et al. (1973) .

$$CSD = ID + MAS$$

where, CSD = cumulative selection differential of a calf,

ID = deviation of calf's record from year-sex-location subclass mean,

MAS = mean accumulated selection differential for parents in the contemporary group.

The MAS for a given contemporary group is calculated as half the weighted average of CSD of sires plus half of the average CSD of dams contributing progeny to the contemporary group. Cumulative selection differentials were regressed on year of birth of progeny to assess the general trend in the amount of selection practiced over the years. The maximum selection differential was calculated by averaging the mean selection differential of bulls with the best index according to line criteria.

Results

Descriptive statistics for traits included in this study are depicted in Tables 1 and 2. In each of the three lines, mean performance of cattle was often higher at Rhodes. Further, there were more observations per line at Rhodes than at McNay, in part because, the study at McNay involved one year less than Rhodes.

Generations of selection

Mean ages for parents of all progeny are shown in Table 3. The average age of parents of all progeny was 4.02, 4.05 and 4.62 years in the small, medium and large lines, respectively. In each line the mean age of parents at Rhodes was often smaller than the corresponding age at McNay. One other important feature is that for any line, the mean age of sires was higher than those of dams. This may be due to the exclusion of the foundation parents in the computation of means. Furthermore, the practice of breeding almost all heifers and use of sires for more than two breeding seasons might have contributed to this trend. Reproductive problems (Buttram and Willham, 1989) and hence the lack of sufficient replacement bulls in the large line seems to have caused a more repeated use and therefore a relatively older mean parental age at McNay.

The mean age of parents for the four paths of gene transmission are depicted in the same table. The average age of parents of the selected sires was smaller than parents of all progeny as well as the mean age for parents of the dam. The overall mean age of parents in the four paths of selection was 3.1, 3.2 and 3.59 years in small, medium and large lines. However, this may not provide an accurate evaluation of generation interval due to exclusion of foundation cattle. Instead, generation intervals computed from generation coefficients could be used.

During the 13 years of the experiment at Rhodes, 2.84 to 3.07 generations of selection were carried out. This provides an average generation interval of 4.33, 4.23 and 4.58 years in small, medium and large lines, respectively. These mean generation interval values in the respective lines were higher than mid-parental mean ages given in the same table. This is because mid-parental ages are computed excluding foundation animals, but in the computation of generation coefficients foundation parents have been assigned a generation coefficient of zero.

At McNay, over the 12 years, a total of 2.89 generations of selection have been conducted in the small and medium lines. In the large line a total of 2.27 generations of selection have been performed. This gives a generation interval of 4.15 in small and medium lines and an interval of 5.29 in the large line. Generally, generation turnover in the large line at both locations was slower than all other lines. The annual increase in generation coefficient (regression of generation coefficient on year) ranged from 0.2 in the large line at McNay to a maximum of 0.29 in the small line at Rhodes.

Selection differential per generation

The mean weighted sire selection differential for the primary trait (IDX) in the small line was similar at both locations (~ 1.28 σ/gen), about 6.3% to 6.5% above the mean index (Table 4). Sire selection accounted for 92%(Rhodes) to 95% (McNay) of the total selection pressure. Computation of secondary sire selection differential for components of the index showed mean values of .35 σ/gen and -0.37 σ/gen for WWT and WHT, respectively Rhodes. The weighted sire selection differential at McNay for WWT and WHT was .37 and -.40, respectively. Furthermore, secondary selection differential values for BWT and BHT were similar in magnitude but opposite in direction.

For medium synthetic cattle the mean selection differential of sires for IDX was -.57 σ/gen and -.36 σ/gen, or 2.1% and 1.2% below the mean for the Rhodes and McNay herds, respectively (Table 5). Based on the results of sire selection differential, the index seems to have favored selection of sires with a higher WWT than the average of the herd. Selected sires at both herds were one standard deviation above the mean. This may be due to the weighting term used in the index equation.

Selection index equations in all lines included a weighting factor of five to account for the smaller phenotypic variance of hip height at weaning. This weighting factor may be adequate considering the standard deviation of WWT and WHT (Tables 1 and 2). However, this may not be true if index equations are using absolute deviations.

Mean selection differential for IDX in large synthetic cattle ranged from .75 σ/gen at McNay to .92 σ/gen at Rhodes, 1.3% and 1.8% above the mean at the respective herds (Table 6). Of the total selection pressure, sire selection accounted to 86% to 95% at McNay and Rhodes, respectively. Sire selection differential for the components of the index (WWT, WHT) were positive at both farms and larger at Rhodes. The realized secondary selection differential for BWT, BHT, ADG and ADH was positive and similar across location.

Dams were culled primarily for reproduction failure. The only exception to this was in later years of the study where dams were removed from the herd on the basis of generation. In the small line, 1985-born heifers were selected based on their weaning index value.

The ratio of weighted to the unweighted sire selection differential can be used to assess effects of natural selection in artificial selection experiments (Falconer, 1989).

These ratios for sires pertaining to the primary trait (IDX) ranged from a minimum of .78 in the medium line to a maximum of 1.09 in the small line, both occurring at McNay. For dams the ranges were from .89 for medium Rhodes to a maximum of 2 for McNay small dams. However, with a small number in the breeding herd these ratios may not provide an accurate description due to the possible effects of chance.

Cumulative selection differential

Cumulative selection differential for a particular trait indicates the amount of previous selection applied on parents of progeny born in any particular year. The regression of cumulative selection differential on year of birth of progeny provides an estimate of the rate of build-up in the amount of selection. The accumulation of selection differential in the earlier years of the experiment was slow and unstable. This was mainly because of the use of the same group of foundation sires in the years 1978-79. This group of sires contributed to about 76% and 23% of the progeny in the years 1980 and 1981, respectively. Generally, such a trend was observed until later years when only few to none of the foundation sires and their sons were used and dams started to influence the cumulative selection differential through MAS. Hence, the regression of cumulative selection differential on year of birth of progeny during the entire period may not provide a good description of the selection process. Instead, the period 1986-90 has been used to calculate the regression coefficients.

The coefficients of regressions for most of the traits were higher at Rhodes than at McNay. At McNay the sire cumulative selection differential for IDX accumulated at a rate of .15 σ/ year in the large synthetic followed by a rate of .11 σ/year in small and medium lines, respectively. At Rhodes the sire cumulative selection differential was similar across all lines at a rate of .16 σ/year.

Except for medium cows at McNay there had been a significant($p < .01$, $P < .05$) increase in the cumulative dam differential both for the IDX and the secondary traits. Therefore, evaluation of the cumulative selection differential based on mid-parental values may provide a better understanding of selection practices in the study.

Figures 1 and 2 depict the trend in mean accumulative mid-parent IDX differential by year and line at both locations. In both herds, the accumulation of selection differential in small and large lines showed a positive slope. However the opposite was true in the medium line. In general, the overall mean cumulative mid-parent index differential was 1.85, .82 and 1.14 σ in small, medium and large lines, respectively. The mean sire contribution was about 62% in small and large lines. In the medium line, cumulative selection differential through sires accounted for 73%.

Evaluation of the mid-parent cumulative selection differential for components of the index showed a different ranking order of lines as compared with the trend for IDX. There was a very rapid rate of buildup in mean mid-parental WWT in medium cattle at both locations (.25 σ/yr). When averaged by line, regression coefficients for mid-parental cumulative differential for

WWT in the small and large lines were .27 times the amount for medium lines.

Computation of regression coefficients thus far has involved data from only the last few years of the study. On the other hand mean mid-parent cumulative selection differential values could be used to recalculate the rate of increase per generation over the entire period of the study. The mean mid-parent WWT cumulative selection differential by line was .69, 2.61 and 1 σ in small, medium and large cattle. When these values are divided by the mean number of generations of selection (Table 3), they provide a rate of .23, .88 and .39 σ/generation for small medium and large lines. For WHT the mean mid-parental cumulative selection differential was .49, .96 and 1.05 σ resulting in a rate of .17, .32 and .41 σ/generation, for small, medium and large lines.

Maximum selection differential

Comparison of the maximum potential selection differential with the realized values for the primary trait helps evaluate effectiveness of a selection program in terms of retaining the intended selection objective. In this regard both extreme values did occur at McNay. In the small line at Rhodes the actual sire index differential per generation was .64 times the maximum potential selection differential. However, almost all of the top ranking sires at McNay had offspring in the next generation.

In the medium synthetic cattle, potential sires were those with index values closer to zero, and there seems to have been a very small use of these sires. In the large cattle about 60% (Rhodes) to 88% (McNay) of the maximum potential sire differential has been realized. However, regardless of the line, had the maximum potential selection been realized, it would have resulted in more emphasis on weaning weight.

During the experiment, selection criteria have been strictly followed. However, losses in potential selection differential could be due to several reasons. Each year almost equal numbers of sires were selected from each location and were used across location within a line. This seems to have limited the use of potential bulls at Rhodes. In addition, each year, mating within each line was made between animals of the same generation, and breed composition of mates needed to be considered. This may have limited sire selection opportunity.

Implications

This project, besides other accomplishments, has enabled researchers to utilize both within and between breed genetic variation to produce three synthetic lines of beef cattle. Particularly, the major portion of size differences between lines was brought about by the initial classification of dams into size-lines and assignment of sires to the respective dam-lines.

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Table 1. Mean and standard deviations of observations used in the analysis (Rhodes).

	TRAIT					
	BWT (kg)	BHT (cm)	WWT (kg)	WHT (cm)	ADG (kg/d)	ADH (cm/d)
Small						
n	1776	1776	1638	1641	1638	1641
Mean	34.7±4.5	68.6±3.9	209.5±27.3	103.7±5.1	.85±.13	.17±.03
Medium						
n	1587	1586	1474	1470	1474	1470
Mean	39.6±5.3	72.6±4.15	238.2±31.9	109.6±5.2	.97±.15	.18±.03
Large						
n	1391	1390	1294	1294	1295	1294
Mean	45.6±6.1	76.3±4.1	257.0±35.2	114.8±5.8	1.03±.2	.19±.02

n = number of observations

Table 2. Mean and standard deviations of observations used in the analysis (McNay).

	TRAIT					
	BWT (kg)	BHT (cm)	WWT (kg)	WHT (cm)	ADG (`kg/d)	ADH (cm/d)
Small						
n	1350	1344	1189	1189	1189	1189
Mean	30.80±4.5	66.5±3.7	196.1±27.2	103.9±5.5	.81±.13	.18±.03
Medium						
n	1187	1179	1018	1018	1018	1010
Mean	35.7±5.7	70.5±4.1	221.3±31.0	108.2±5.6	.91±.14	.18±.03
Large						
n	800	799	684	683	684	683
Mean	42.4±6.8	75.5±4.37	245.3±33.8	115.2±5.9	.99±.15	.19±.03

n = number of observations

Table 3. Mean parental age, number of generations of selection and regression of mean generation coefficient on year.

	Small		Medium		Large	
	McNay	Rhodes	McNay	Rhodes	McNay	Rhodes
	-----Parents of all progeny-----					
Age, years						
Sire	4.66	4.03	4.48	4.16	6.07	4.20
Dam	3.64	3.77	3.75	3.75	4.39	3.82
Mid-parent	4.15	3.90	4.12	3.96	5.23	4.01
Generations	2.89	3.0	2.89	3.07	2.27	2.84
Regression	.25±.004**	.29±.004**	.24±.004**	.26±.004**	.20±.01**	.25±.004**
	-----Parents of selected progeny-----					
Age, years						
Sires of Sires	3.07	2.73	3.17	3.03	2.98	3.36
Dams of sires	2.60	2.49	2.72	2.94	2.84	3.20
Sires of dams	4.08	3.27	4.29	3.62	5.18	3.67
Dams of dams	3.28	3.07	3.55	3.19	4.06	3.39

Table 4. Mean weighted selection differentials per generation in small synthetic cattle.

	Traits						
	BWT	BHT	WWT	WHT	IDX	ADG	ADH
	-----Rhodes-----						
Sire	.02	-.33	.35	-.37	1.28	.34	-.11
Dam	.06	.00	.14	0	.11	.02	.02
Mid-parent	.04	-.16	.24	-.18	.70	.18	-.05
	-----McNay-----						
Sire	.03	-.34	.37	-.40	1.27	.38	-.12
Dam	0	.06	.08	.08	.06	.09	.05
Mid-parent	.02	-.14	.22	-.16	.67	.24	-.04

* in standard deviation units

Table 5. Mean weighted selection differentials per generation in medium synthetic cattle.

	Traits*						
	BWT	BHT	WWT	WHT	IDX	ADG	ADH
	------------Rhodes------------						
Sire	.97	.89	1.09	.41	-.57	1.03	.17
Dam	.96	.88	.99	.48	-.06	.89	.26
Mid-parent	.97	.88	1.04	.45	-.32	.96	.22
	------------McNay------------						
Sire	.81	.75	1.01	.33	-.36	.98	.13
Dam	.84	.47	.66	.25	-.03	.60	.16
Mid-parent	.82	.61	.84	.29	-.20	.79	.15

* in standard deviation units

Table 6. Mean weighted selection differentials per generation in large synthetic cattle.

	Trait*						
	BWT	BHT	WWT	WHT	IDX	ADG	ADH
	------------Rhodes------------						
Sire	.29	.25	.78	.86	.92	.78	.64
Dam	0	.17	-.05	.07	.05	.08	.02
Mid-parent	.14	.21	.37	.43	.46	.43	.33
	------------McNay------------						
Sire	.22	.25	.77	.75	.75	.78	.63
Dam	-.03	-.02	.09	.07	.12	.09	.43
Mid-parent	.09	.11	.43	.41	.44	.44	.52

* in standard deviation units

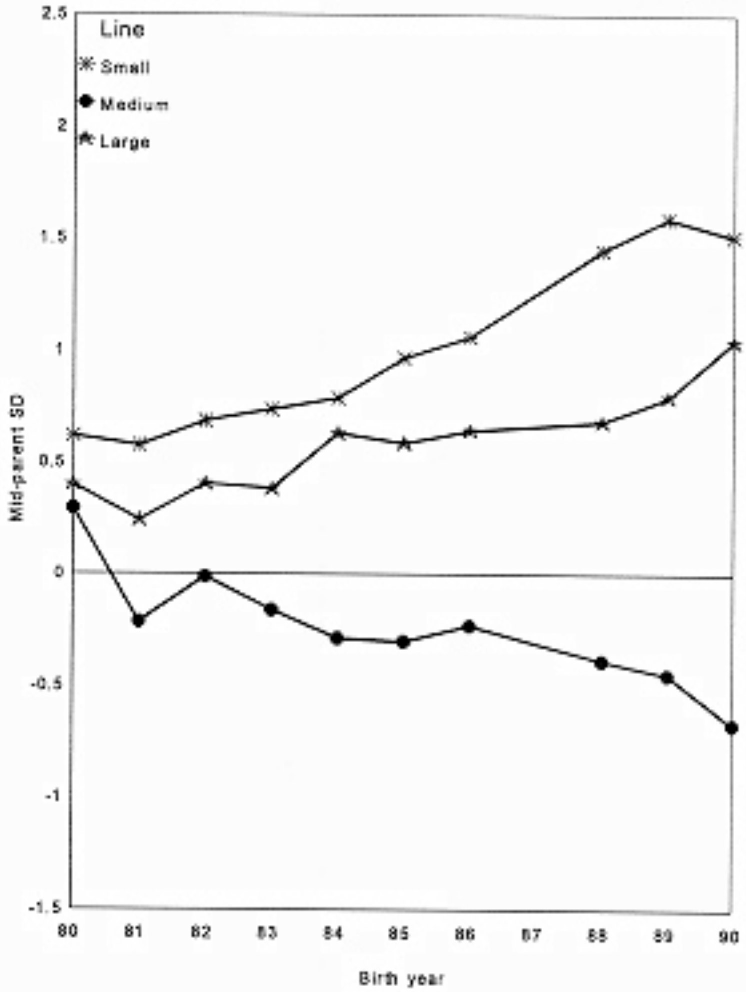

Figure 1. The general trend in mid-parent cumulative selection differential, McNay.