Selection for Weaning Weight and Postweaning Gain in Hereford Cattle. III. Correlated Responses to Selection in Milk Yield, Preweaning and Postweaning Traits


North Carolina State University, Raleigh 27695-7621

Summary

Single trait selection was practiced in three lines of Hereford cattle. Bulls were selected within sire families for increased weaning weight (WW) in the WW line (WWL), for postweaning gain (PG) in the PG line (PGL) and at random in the control line (CTL). Correlated responses to selection indicated that predicted milk yield in cows and preweaning daily gain and yearling weight in bulls and heifers were genetically improved in both WWL and PGL. Larger correlated responses were observed in PGL than in WWL. Birth weight in bulls and heifers increased in PGL but no genetic change was observed in WWL. Feed efficiency, feed intake and fatness were evaluated in bulls on postweaning feedlot test. No significant correlated responses in feed efficiency were observed in either line. Larger correlated responses in feed intake were observed in PGL bulls than in WWL bulls, while fatness was significantly increased in both selection lines.

(Key Words: Selection, Beef Cattle, Milk Yield, Growth, Feed Efficiency, Fat.)

Introduction

In choosing efficient breeding schemes, breeders should consider not only the direct response to selection in a specific trait or index of traits but also correlated responses in other traits.

Effects of selection for growth traits on other growth and carcass traits and maternal performance are not always clear. Willham (1972) indicated that selection for weaning weight results in more accurate selection for preweaning growth than for maternal performance. Christian et al. (1965) suggested that selecting heifers genetically superior in weaning weight would result in increased genetic value for growth response but decreased milk production. Sejrsen (1978), however, indicated that animals with high genetic growth capacity would seem to have higher growth hormone concentration in the blood and consequently better mammary growth and higher milk yield. Robison (1981) suggested that selection for maternal effects should be based on weight of calves at 90 d or on direct estimates of milk production. It seems important, therefore, to investigate not only the effects of milk yield on growth traits but also the effects of selection for increased growth rate traits on milk yield.

Selection for growth rate traits should consider correlated responses in birth weight because increases in birth weight are associated with calving difficulty, survival potential of calves and rebreeding performance of cows (Laster et al., 1973). Koch et al. (1974) indicated that selection with total emphasis on postnatal growth rate rather than on weaning or yearling weight could substantially reduce the expected increase in birth weight.

Despite the great economic importance of feed intake and feed efficiency in beef cattle, genetic gains in these traits have not been evaluated in many recent selection experiments. Heritabilities and genetic correlations were reported by Koch et al. (1963), Bailey et al. (1971) and Mavrogenis et al. (1978). Correlated responses in fat deposition from selection for increased weaning weight or yearling weight
would be expected to be positive (Koch, 1978), especially at a constant age (Koch et al., 1982).

This study was undertaken to evaluate correlated responses in milk yield and in pre- and postweaning traits to selection for increased weaning weight and postweaning gain in Hereford cattle.

**Materials and Methods**

Single trait selection was practiced in three lines of Hereford cattle. Bulls were selected within sire families for increased weaning weight (WW) in the WW line (WWL), for postweaning gain (PG) in the PG line (PGL) and at random in the control line (CTL). Additional traits measured were predicted milk yield (PMY) in cows, birth weight (BWT), preweaning daily gain (PRWDG) and yearling weight (YWT) in bulls and heifers and feed efficiency (FE), feed intake (FI) and fatness (FAT) in bulls on feedlot test during the postweaning period (205 to 365 d of age). Data utilized in the analyses reported here included measurements on calves and their dams born from 1967 through 1981.

Milk yield was evaluated each year for all cows born from 1967 to 1978 using the calf-suckling technique (Rutledge et al., 1971). Predicted milk yield represents the amount of milk obtained by calves from their dams during 24 h in seven monthly measures and was estimated using equations given by Rutledge et al. (1972). Maximum likelihood constants obtained by Robison et al. (1978) were utilized to adjust PMY for age of dam. Calves were weighed within 24 h of birth and at weaning. Birth weight and PRWDG were adjusted for age of dam using multiplicative factors (Irgang, 1984; E. U. Dillard, personal communication). Yearling weight was 205-d weight adjusted for age of dam plus PG. Bulls were individually fed a complete mixed diet twice daily and heifers were maintained on pasture during the postweaning period. Feed efficiency was expressed as the bulls’ feed to gain ratio and FI represents the total amount of feed consumed by bulls from 205 to 365 d. Fatness in bulls at 1 yr of age was measured over the longissimus muscle using an ultrasonic scanner.

**Environmental and Genetic Time Trends.**

Environmental time trends were obtained by regressing the CTL year means for each trait on calf birth year. A second estimate of environmental time trend was obtained by regressing genetic effects on calf birth year and represent correlated responses to selection per year.

Environmental time trends for all traits are presented in table 1. Negative time trends in CTL were observed for all traits except feed intake. Trends from multiple regression analyses were negative, except for feed intake and efficiency, and usually were smaller than trends observed in CTL.

Correlated responses in milk yield observed in WWL and PGL, based on the year when the calves were born, are presented in figure 1. The graph indicates that responses increased up to 1980 and then decreased in 1981. After 1971, responses were larger and less variable in PGL than in WWL.

Correlated responses in BWT were variable. However, while correlated responses fluctuated around zero in WWL, they were usually positive in PGL in both bulls and heifers (figure 2). With the exception of the years 1980 and 1981, correlated responses in PRWDG were usually higher in PGL than in WWL and were variable in heifers (figure 3). Responses in YWT resulting from the effects of selection on WW and PG are shown in figure 4. Correlated genetic gains of approximately 30 and 15 kg in YWT were observed in bulls of PGL and WWL, respectively. Correlated responses in YWT of
TABLE 1. ENVIRONMENTAL TIME TRENDS FOR PREDICTED MILK YIELD, BIRTH WEIGHT, PREWEANING DAILY GAIN, YEARLING WEIGHT, FEED EFFICIENCY, FEED INTAKE AND FATNESS IN CONTROL LINE AND ENVIRONMENTAL ESTIMATES

<table>
<thead>
<tr>
<th>Trait</th>
<th>Unit</th>
<th>Sex</th>
<th>Control line</th>
<th>Environmental estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted milk yield</td>
<td>(kg/yr)</td>
<td>Bull</td>
<td>-.17 ± .14 NS</td>
<td>-.13 ± .10 NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heifers</td>
<td>-.11 ± .06†</td>
<td>-.08 ± .05 NS</td>
</tr>
<tr>
<td>Birth weight</td>
<td>(kg/yr)</td>
<td>Bull</td>
<td>-.05 ± .06 NS</td>
<td>-.04 ± .05 NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heifers</td>
<td>-.05 ± .06 NS</td>
<td>-.04 ± .05 NS</td>
</tr>
<tr>
<td>Preweaning daily gain</td>
<td>(g·d⁻¹·yr⁻¹)</td>
<td>Bull</td>
<td>-10.2 ± 2.5**</td>
<td>-7.8 ± 1.8***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heifer</td>
<td>-7.4 ± 1.9***</td>
<td>-4.7 ± 1.3**</td>
</tr>
<tr>
<td>Yearling weight</td>
<td>(kg/yr)</td>
<td>Bull</td>
<td>-1.6 ± .8†</td>
<td>-1.1 ± .8 NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heifer</td>
<td>-1.6 ± .9†</td>
<td>-1.1 ± .7 NS</td>
</tr>
<tr>
<td>Feed efficiency</td>
<td>(feed/gain)/yr</td>
<td>Bull</td>
<td>-.006 ± .016 NS</td>
<td>.007 ± .013 NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heifer</td>
<td>-.006 ± .016 NS</td>
<td>.007 ± .013 NS</td>
</tr>
<tr>
<td>Feed intake</td>
<td>(kg/yr)</td>
<td>Bull</td>
<td>4.3 ± 2.6 NS</td>
<td>6.5 ± 3.5†</td>
</tr>
<tr>
<td>Fatness</td>
<td>(mm/yr)</td>
<td>Bull</td>
<td>-.11 ± .04*</td>
<td>-.06 ± .04 NS</td>
</tr>
</tbody>
</table>

*aStandard errors from regression analysis.

bEnvironmental estimates from multiple regression procedure.

cNS = nonsignificant.

†P<.10.

*P<.05.

**P<.01.

***P<.001.

Heifers were smaller and more variable than in bulls but also were larger in PGL than in WWL.

Correlated responses in efficiency, feed intake and fatness of bulls are presented in figure 5. Efficiency appeared to change very little in either select line during the course of the experiment. Correlated responses in feed intake

![Figure 1](image1.png)  
**Figure 1.** Correlated responses in milk yield to selection for weaning weight (WWL) and postweaning gain (PGL), as deviated from environmental estimates.

![Figure 2](image2.png)  
**Figure 2.** Correlated responses in birth weight in bulls and heifers to selection for weaning weight (WWL) and postweaning gain (PGL), as deviated from environmental estimates.
Figure 3. Correlated responses in preweaning daily gain in bulls and heifers to selection for weaning weight (WWL) and postweaning gain (PGL), as deviated from environmental estimates.

were larger in PGL than in WWL bulls. Increases in fatness were observed in both selection lines throughout the experiment.

Genetic Time Trends. Genetic time trends represent estimates of correlated responses to selection per year in WWL and PGL (table 2). Genetic gains in PMY were positive in both WWL and PGL. Gains were larger in PGL than in WWL. For BWT, correlated responses to selection were essentially zero in WWL in bulls and heifers but were increasing at about .10 kg/yr in PGL. Positive genetic time trends were observed for PRWDG and YWT in both lines and sexes, but larger correlated gains were observed in PGL than in WWL. Negative trends in FE would be desirable. In WWL, both genetic time trend estimates were positive while in PGL one estimate was positive and the other was negative; the genetic changes were not significant in either line. Genetic time trends for feed intake were approximately twice as large in PGL as in WWL. Genetic time trends for FAT

Figure 4. Correlated responses in yearling weight in bulls and heifers to selection for weaning weight (WWL) and postweaning gain (PGL), as deviated from environmental estimates.

Figure 5. Correlated responses in feed efficiency, feed intake and fatness in bulls to selection for weaning weight (WWL) and postweaning gain (PGL), as deviated from environmental estimates.
### TABLE 2. GENETIC TIME TRENDS FOR PREDICTED MILK YIELD, BIRTH WEIGHT, PREWEANING DAILY GAIN, YEARLING WEIGHT, FEED EFFICIENCY, FEED INTAKE AND FATNESS IN WEANING WEIGHT LINE AND POSTWEANING GAIN LINE

<table>
<thead>
<tr>
<th>Trait</th>
<th>Unit</th>
<th>Sex</th>
<th>Weaning weight line</th>
<th>Postweaning gain line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deviation from</td>
<td>Deviation from</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CTL&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Env. est.&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Predicted milk yield</td>
<td>(kg/yr)</td>
<td>B</td>
<td>.21 ± .12 NS&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.17 ± .08†</td>
</tr>
<tr>
<td>Birth weight</td>
<td>(kg/yr)</td>
<td></td>
<td>.01 ± .06 NS</td>
<td>-.03 ± .06 NS</td>
</tr>
<tr>
<td>Preweaning daily gain</td>
<td>(g·d&lt;sup&gt;-1&lt;/sup&gt;·yr&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>B</td>
<td>5.0 ± 2.4†</td>
<td>2.7 ± 1.4†</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>2.7 ± 1.8†</td>
<td>0 ± .8 NS</td>
</tr>
<tr>
<td>Yearling weight</td>
<td>(kg/yr)</td>
<td>B</td>
<td>1.5 ± .7†</td>
<td>1.0 ± .4*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>.7 ± .5 NS</td>
<td>.3 ± .2 NS</td>
</tr>
<tr>
<td>Feed efficiency</td>
<td>(feed/gain)/yr</td>
<td>B</td>
<td>.034 ± .021 NS</td>
<td>.012 ± .008 NS</td>
</tr>
<tr>
<td>Feed intake</td>
<td>(kg/yr)</td>
<td>B</td>
<td>4.7 ± 2.8 NS</td>
<td>2.6 ± 1.3†</td>
</tr>
<tr>
<td>Fatness</td>
<td>(mm/yr)</td>
<td>B</td>
<td>.17 ± .04**</td>
<td>.12 ± .02***</td>
</tr>
</tbody>
</table>

<sup>a</sup>Standard errors from regression analysis.
<sup>b</sup>B = bulls; H = heifers.
<sup>c</sup>CTL = control line; Env. est. = environmental estimates from multiple regression procedure.
<sup>d</sup>NS = nonsignificant.
†P<.10.
*P<.05.
**P<.01.
***P<.001.
were very similar in the two lines and indicate that deposition of fat was genetically increased in bulls on feedlot throughout the experiment.

Regression of Correlated Responses to Selection on Cumulative Selection Differentials. Regressions of response in PMY, BWT, PRWDG, YWT, FE, FI and FAT on cumulative selection differentials are presented in table 3.

Regression coefficients for PMY on CSD were very similar for both methods within each selection line. Correlated responses in BWT in both sexes obtained from each unit of selection applied to PG were much larger than correlated responses resulting from each unit of selection applied to WW. Values obtained for PRWDG and YWT followed the same tendency but with much smaller differences. Regression coefficients for FE were positive in both WWL and PGL from method I but negative when calculated with method II. Correlated responses in FI from each unit of selection applied to PG were much higher than for each unit of selection applied to WW. Regressions obtained for FAT, however, were similar in the two lines.

Discussion

The decision whether milk yield should be genetically improved in beef cattle depends on the production system, on the cows' rebreeding performance and on the level of genetic improvement of growth traits attained in the population (Willham, 1972; Cundiff and Gregory, 1977; Notter et al., 1979). Milk yield is the most important postnatal maternal effect on early growth traits in beef cattle (Rutledge et al., 1971; Koch, 1972; Willham, 1972). Robison et al. (1978) reported that 40% of the variance in 205-d weight could be attributed to the direct influence of the dam's milk yield. Phenotypic correlations between milk yield, total or cumulative milk production and gain from birth to weaning or WW are of the order of .5 to .8 (Koch, 1972; Robison et al., 1978). Genetic relationships between maternal effects and growth rate are, however, usually negative (Vesely and Robison, 1971; Robison, 1981).

Dickey et al. (1982) reported positive genetic correlations between milk yield and pre- and postweaning growth traits in Angus cows but negative genetic correlations in Hereford cows. Mavrogenis et al. (1978) reported negative covariances between direct and maternal effects for WW, PG, YWT, FE, FI and FAT traits. Christian et al. (1965) indicated that selection for higher weaning weight in heifers could possibly result in decreased milk production. Mangus and Brinks (1971) observed that heifers from a high WW group produced offspring with lower WW than heifers from a low WW group, suggesting a negative environmental correlation between dams and their progeny. This could result from excess fat deposition in the mammary tissue of heifers raised by superior milking dams, thus lowering their milk production potential and affecting WW of their progeny (Willham, 1972). Results obtained in this experiment indicate, however, that milk yield in cows was positively correlated genetically with WW and PG because it was improved in both WWL and PGL. This seems to agree with the suggestions made by Sejrsen (1978). He postulated that animals with high genetic growth capacity would have higher growth hormone concentration in the blood and consequently better mammary tissue growth resulting in higher milk production. In this case, improvement of growth through selection would not necessarily lead to a decline in milk yield but would lead to increased milk production of dams and hence provide an impulse on early growth rate of calves.

Genetic increases in BWT might not always be a desirable breeding goal. Birth weight was identified by Bellows et al. (1971) as the most important factor affecting calving difficulty in a sample of Hereford and Angus cows, and calving difficulty is associated with reduced calf survival and rebreeding performance of dams (Brinks et al., 1973; Laster et al., 1973; Cundiff and Gregory, 1977). Correlated responses to selection in BWT were practically zero in WWL, which differs from results obtained by Flower et al. (1964), Chenette et al. (1981) and Buchanan et al. (1982); while results obtained for BWT in PGL were much higher but still lower than correlated responses to selection for WW or YWT reported by the same authors.

Improvement of WW of beef calves is dependent primarily upon increased preweaning growth potential of calves and maternal ability of cows (Mangus and Brinks, 1971). Larger correlated responses in PRWDG to selection for PG than for WW confirm results obtained in this same experiment by Irgang et al. (1985), who reported larger correlated responses in WW from selection for PG than direct responses to selection for WW. This could have been caused by larger genetic improvements of milk yield in PGL than in WWL.

Larger correlated responses in YWT for PGL
<table>
<thead>
<tr>
<th>Trait</th>
<th>Unit</th>
<th>Sexc</th>
<th>Weaning weight line</th>
<th></th>
<th>Postweaning gain line</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Methodb</td>
<td>I</td>
<td>II</td>
<td>Methodb</td>
</tr>
<tr>
<td>Predicted milk yield</td>
<td>(kg)</td>
<td></td>
<td>.09 ± .04*</td>
<td>.06 ± .04†</td>
<td>.08 ± .03*</td>
<td>.11 ± .04**</td>
</tr>
<tr>
<td>Birth weight</td>
<td>(g)</td>
<td>B</td>
<td>5.5 ± 18.8 NSd</td>
<td>-3.6 ± 11.8 NS</td>
<td>31.4 ± 23.8 NS</td>
<td>24.2 ± 11.6*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>10.2 ± 19.2 NS</td>
<td>4.7 ± 11.4 NS</td>
<td>10.5 ± 19.2 NS</td>
<td>10.1 ± 12.0 NS</td>
</tr>
<tr>
<td>Preweaning daily gain</td>
<td>(g/d)</td>
<td>B</td>
<td>.4 ± .8†</td>
<td>.5 ± .3†</td>
<td>1.7 ± .4**</td>
<td>1.0 ± .3***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>.9 ± .6†</td>
<td>.1 ± .3 NS</td>
<td>1.6 ± .6***</td>
<td>.5 ± .3***</td>
</tr>
<tr>
<td>Yearling weight</td>
<td>(kg)</td>
<td>B</td>
<td>.51 ± .22*</td>
<td>.34 ± .11**</td>
<td>.78 ± .12***</td>
<td>.57 ± .11***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>.31 ± .14*</td>
<td>.17 ± .08*</td>
<td>.40 ± .13***</td>
<td>.21 ± .09**</td>
</tr>
<tr>
<td>Feed efficiency</td>
<td>(feed/gain)</td>
<td>B</td>
<td>.008 ± .007 NS</td>
<td>-.003 ± .002 NS</td>
<td>.001 ± .004 NS</td>
<td>-.001 ± .002 NS</td>
</tr>
<tr>
<td>Feed intake</td>
<td>(kg)</td>
<td>B</td>
<td>1.4 ± .9 NS</td>
<td>.70 ± .41*</td>
<td>2.2 ± .6**</td>
<td>1.79 ± .42**</td>
</tr>
<tr>
<td>Fatness</td>
<td>(mm)</td>
<td>B</td>
<td>.05 ± .01**</td>
<td>.02 ± .01**</td>
<td>.04 ± .01*</td>
<td>.03 ± .01**</td>
</tr>
</tbody>
</table>

aStandard errors from regression analysis.
b1: selected lines deviated from control line; II: selected lines deviated from environmental estimates obtained from multiple regression procedure.
cB = bulls; H = heifers.
dNS = nonsignificant.
†P<.10.
*P<.05.
**P<.01.
***P<.001.
than for WWL calves would be expected based on results presented for PRWDG, WW and PG. Estimates of genetic correlations reported by Koch et al. (1974) and Buchanan et al. (1982) in bulls and heifers ranged from .61 to .74 between WW and YWT and from .78 to .96 between postweaning daily gain and YWT and suggest, as observed in this experiment, that YWT is expected to improve from selection for either WW or PG but more rapidly from selection for PG. Larger correlated responses in YWT for bulls than for heifers were observed by Newman et al. (1973) and Barlow (1979), also. Buchanan et al. (1982), however, reported larger responses in YWT in heifers (550-d of age) than in bulls (452-d of age).

Feed efficiency is one of the most important economic traits in beef cattle. However, because measurement requires individual feeding, genetic progress in FE has been dependent on correlated response from selection for rate of gain. Koch et al. (1963) reported a genetic correlation of .79 between the ratio of gain to feed and gain, suggesting that selection for gain should lead to increased feed efficiency. Correlated responses in FE in this experiment, however, were small and nonsignificant in both WWL and PGL and tend to confirm the .07 genetic correlation between FE and PG reported by Mavrogenis et al. (1978) in the same experiment up to 1975, indicating that genes for the two traits were independent and that direct selection for FE could be a necessary alternative. Individual feeding, as practiced in this experiment, however, may be under different genetic control than group feeding, which is more representative of industry practice.

Selection for increased WW and PG was accompanied by increased FI, which is in agreement with positive genetic correlations between FI and postweaning rate of gain (Koch et al., 1963; Mavrogenis et al., 1978). Larger correlated responses in FI to PG selection than to WW selection agree with larger PG genetic gains in PGL bulls than in WWL bulls reported in the second paper of this series (Irgang et al., 1985). Results from this experiment indicate also that selection for increased WW and PG should lead to increased amounts of fat deposition in yearling bulls, which is in accord with results reported by Koch (1978) and Koch et al. (1982).

In this paper, selection responses were estimated by two related methods. Method I represents a more classical approach to the analysis of selection experiments utilizing control lines, especially when generations are not discrete. For reasons discussed in the second paper of this series, method II is preferred. Standard errors for regression coefficients estimated from method II were consistently smaller than standard errors from method I.

Results obtained from this experiment indicate that selection for WW and PG should be effective in increasing PMY, PRWDG, YWT and FI although larger correlated responses would be expected from PG selection. Selection for either WW or PG would increase the amount of FAT in bulls but should not result in any significant change in FE. Also, while selection for PG should increase BWT, selection for WW would not be expected to change BWT significantly.

**Literature Cited**


