RESULTS FROM CROSSING BEEF × BEEF AND BEEF × DAIRY BREEDS: CALF PERFORMANCE TO WEANING

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HETEROSIS is utilized to increase production in the swine, poultry and sheep industries. It is less extensively utilized by the commercial beef industry in the United States and Canada, but interest in crossbreeding for beef production is apparent.

Additional information is needed to satisfy inquiries concerning the use of the Charolais and Brown Swiss breeds for crossing. Temple (1965) described the status of crossbreeding investigations involving Charolais cattle in the United States. Klosterman et al. (1965) and Sagebiel et al., (1967a, b) reported heterotic effects on some traits from crossing the Charolais with British breeds. In a comprehensive review of crossbreeding studies involving beef, dairy and dual purpose breeds by Mason (1966), information on the use of the Brown Swiss breed was lacking.

Among the more recent reports of heterotic effects on preweaning and weaning traits from crossing British beef breeds were those by Gregory et al. (1965) and Gaines et al. (1966). The latter authors adequately cited earlier results of a pertinent nature from crossing British breeds with Brahman (Zebu) cattle.

The primary objective of the present study was to estimate heterosis in birthweight, preweaning daily gain, weaning weight and weaning score by comparing calves of all reciprocal, two-breed crosses among the Hereford, Angus and Charolais breeds with straightbred calves of these breeds. As an extension of the main study, Brown Swiss dams were compared with dams of the three beef breeds as producers of first-cross calves for beef. Estimates of heterosis in reproduction will be presented in another paper.

Materials and Methods

The data were collected at the United States Range Livestock Experiment Station, Miles City, Montana, on calves born from 1962 through 1965. The experimental design, along with the total number of calves weaned by breeding group and sex class, is shown in table 1.

Three sires of each beef breed (Hereford, Angus and Charolais) were used annually to head nine single-sire complements of about 22 cows each. All sires were changed each year. At the beginning of each breeding season, the Hereford, Angus, Charolais and Brown Swiss females were randomly distributed within age and breed of female among the single-sire complements. Any given sire thus headed a group of about six females of each beef breed, plus four Brown Swiss females. Once they were assigned to the breeding herd, the females were used continuously in the study as long as they remained reasonably sound physically, were apparently capable of producing calves and could support their calves to weaning age.

Hereford females used in the crossbreeding experiment were drawn from a grade herd maintained at the U. S. Range Livestock Experiment Station. The ancestry of these animals traced to about eight private herds. Angus, Charolais and Brown Swiss females were purchased in preparation for the study. Some of these purchased animals, their female offspring in dam at time of purchase and their heifer calves bred and born on the station through the calving season of 1961 were used as breeding animals in the experiment. The Charolais females actually used in the experimental breeding herd were about three-fourths to seven-eighths Charolais, with Hereford and a limited amount of Brahman breeding making up the remainder. The purchased Angus females came from one commercial herd, but these females traced to sires from a variety of sources. The purchased Charolais females were obtained from one herd but were of rather divergent breeding. The Brown Swiss
TABLE 1. EXPERIMENTAL DESIGN AND NUMBER OF OFFSPRING BY BREEDING GROUP AND SEX

<table>
<thead>
<tr>
<th>Breed of sire</th>
<th>Hereford</th>
<th>Angus</th>
<th>Charolais</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M^a F^b</td>
<td>M  F</td>
<td>M  F</td>
<td>M  F</td>
</tr>
<tr>
<td>Breed of dam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hereford</td>
<td>25 30</td>
<td>25 33</td>
<td>24 27</td>
<td>74</td>
</tr>
<tr>
<td>Angus</td>
<td>33 29</td>
<td>38 20</td>
<td>23 32</td>
<td>94</td>
</tr>
<tr>
<td>Charolais</td>
<td>28 27</td>
<td>23 26</td>
<td>25 30</td>
<td>76</td>
</tr>
<tr>
<td>Total</td>
<td>86 86</td>
<td>86 79</td>
<td>72 89</td>
<td>244</td>
</tr>
<tr>
<td>Brown Swiss</td>
<td>20 12</td>
<td>20 10</td>
<td>14 12</td>
<td>54</td>
</tr>
</tbody>
</table>

^a M and F=steer and heifer calves, respectively.

cattle were initially assembled by purchase from private herds and public auctions.

Heifer replacements of each breed were drawn at random from the offspring produced through 1961 by the cows previously described. These heifers were first bred at 2 yr. of age. Heifers produced from the experimental matings were used in a second phase of the crossbreeding investigations. For this reason, there were no replacement heifers available for the fourth breeding season.

All sires of experimental calves were from off-station sources. Two Charolais sires were of seven-eighths and fifteen-sixteenths Charolais breeding. The remaining sires of all breeds were purebreds. Only in the case of the Charolais did sires come more than once from a given herd. Two Charolais sires of the 1962 calves and two Charolais sires of the 1965 calves were secured from the same breeder because of limited availability of suitable sires within a reasonable distance. In selecting sires, attempts were made to obtain individuals somewhat above average in growthiness and conformation, but detailed performance records were not prerequisite to selection.

Breeding females were segregated into single-sire complements only during the June-July breeding seasons of 45 days in 1961 and 1964, and 60 days in 1962 and 1963. All breeding females were consolidated in a single herd during the remainder of each year. The cow herd was maintained under pasture or range conditions most of the year. Dependent upon forage availability and weather conditions, protein supplement or pelleted barley was fed on pasture or range during late fall and early winter in quantities necessary to maintain thrifty condition. During severe winter weather, alfalfa hay and grass hay of variable species composition was provided.

The calves were dropped between March 15 and May 31. Male calves were castrated at the end of the calving season after two males from each breed cross involving Hereford, Angus and Charolais cows and one male from each breed cross involving Brown Swiss cows were selected at random for retention as bulls. These bull calves were retained for a study of sexual development to be reported in another paper. The steer and bull calves were managed alike to weaning age. All calves remained with their dams until mid-October to late October when they were weaned, weighed and scored.

Prior to statistical analysis, the weaning weight of each steer or heifer calf was adjusted to a standard age of 205 days by adding preweaning daily gain of the individual × 205 to birthweight. The daily gain of each bull calf was adjusted to a steer calf basis by a multiplicative factor, 0.95, computed from data on the steer and bull calves involved in the study. Adjusted daily gain was then used to compute weaning weight on a steer basis at the standard age. Because most male calves were castrated at an early age and intact males were adjusted to a steer basis to the extent necessary, male calves are commonly designated as steers in this paper.

Adjustments for differences in age of dam were not made prior to the statistical analyses and the age-of-dam variable was omitted from the model. Age-of-dam classes were nearly proportionate. It appeared that including age-of-dam and age-of-dam × breed-of-dam would remove variation associated with true breed differences.

The data on steer and heifer calves were analyzed separately by least-squares procedures. Main effects and interactions included in the model were breed of sire, breed of dam, breed of sire × breed of dam, year, sire within breed of sire within year, and lactation status (wet or dry) the previous fall. The model used
in all analyses reported in this paper, with appropriate notations, was:

\[ Y_{ijklmn} = \mu + s_i + d_j + (sd)_{ij} + y_k + b_{ik} + l_m + e_{ijklmn} \]

The analyses were first run with the data on progeny of Brown Swiss females excluded. Because Brown Swiss bulls were not used in the mating scheme, straightbred Brown Swiss calves and reciprocals of the Brown Swiss crosses shown in table 1 were not available. The initial analyses were used to evaluate the three beef breeds functioning as breed of sire and breed of dam and to estimate heterosis. Heterosis was estimated from the means computed for straightbred and crossbred calves by combining the constants for breed of sire, breed of dam and breed-of-sire \( \times \) breed-of-dam interaction.

The analyses were repeated with the data on progeny of Brown Swiss females included. The means derived from these analyses were used to compare Brown Swiss dams with dams of the three beef breeds as producers of crossbred calves.

**Results and Discussion**

**Analyses of Variance.** The mean squares by sex classes, with the data on Brown Swiss crosses omitted, are shown in table 2. Year effects were highly significant for preweaning gain and weaning weight of heifers only and for weaning score of both steers and heifers. Although the direction of year-to-year fluctuations in preweaning growth was identical for steers and heifers, the range in weaning weight means of heifers over the 4 yr. exceeded that of steers by 10 kilograms. The direction of year-to-year fluctuations in weaning score was identical for steers and heifers. Fluctuations in score were not associated appreciably with fluctuations in weight.

The effect of breed of sire was highly significant for all traits in both sexes. Sires of the same breed within years differed significantly \((P < 0.01)\) only in the birthweights of heifer calves.

The mean square for sires within breed of sire within year should be the appropriate denominator mean square for testing significance of year and breed-of-sire effects. This mean square, however, was smaller than the residual mean square for each trait of steer calves, due to a negative sire variance component. The residual mean squares were, therefore, used to test all year and breed-of-sire effects (table 2). This seemed to provide more reasonable and conservative tests for the data on steers. The significance of year and breed-of-sire effects on heifer calves was nearly the same regardless of the denominator used. Because of the negative sire variance components cited, only the residual mean squares were used in computing standard errors for \( t \) tests (tables 3 through 6).

Breed of dam had an important \((P < 0.01)\) influence on all traits of both sexes with the exception of weaning score of heifers. Ranking of the three breeds as dams on the basis of weaning score of calves did, however, remain the same regardless of the sex of offspring considered.

Breed-of-sire \( \times \) breed-of-dam interaction was important \((P < 0.05\) and \(P < 0.01\), respectively) for the observed growth traits and weaning score of steers, but it was nonsignifi-

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Birthweight</th>
<th>ADG birth</th>
<th>205-day</th>
<th>Weaning score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M&lt;sup&gt;b&lt;/sup&gt;</td>
<td>F&lt;sup&gt;b&lt;/sup&gt;</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>Breed of sire</td>
<td>2</td>
<td>868.58**</td>
<td>739.48**</td>
<td>0.0629*</td>
<td>0.1182*</td>
</tr>
<tr>
<td>Breed of dam</td>
<td>2</td>
<td>259.48**</td>
<td>177.42**</td>
<td>0.4163**</td>
<td>0.1956**</td>
</tr>
<tr>
<td>BS x BD</td>
<td>4</td>
<td>53.86*</td>
<td>10.69</td>
<td>0.0255*</td>
<td>0.0060</td>
</tr>
<tr>
<td>Year</td>
<td>3</td>
<td>19.83</td>
<td>13.26</td>
<td>0.0138</td>
<td>0.0047**</td>
</tr>
<tr>
<td>S/BS/Y</td>
<td>24</td>
<td>2.53</td>
<td>36.54**</td>
<td>0.0063</td>
<td>0.0100</td>
</tr>
<tr>
<td>Lactation status</td>
<td>1</td>
<td>111.55*</td>
<td>49.79</td>
<td>0.0008</td>
<td>0.0035</td>
</tr>
</tbody>
</table>

* Data on progeny of Brown Swiss females excluded.

** P<0.05.

* * P<0.01.
TABLE 3. LEAST-SQUARES MEANS FOR BREED OF SIRE AND BREED OF DAM WITHIN SEX OF CALF

<table>
<thead>
<tr>
<th>Breeds of parent</th>
<th>Birthweight</th>
<th>ADG birth to weaning</th>
<th>205-day weaning wt.</th>
<th>Weaning score*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Breed of sire</td>
<td>Breed of dam</td>
<td>Breed of sire</td>
<td>Breed of dam</td>
</tr>
<tr>
<td>Steer calves</td>
<td>kg.</td>
<td>kg.</td>
<td>kg.</td>
<td>units</td>
</tr>
<tr>
<td>Hereford</td>
<td>36.1</td>
<td>38.3**</td>
<td>0.890</td>
<td>218.6</td>
</tr>
<tr>
<td>Angus</td>
<td>35.1</td>
<td>35.4</td>
<td>0.914</td>
<td>227.6</td>
</tr>
<tr>
<td>Charolais</td>
<td>41.6</td>
<td>39.1**</td>
<td>0.949</td>
<td>236.2</td>
</tr>
<tr>
<td></td>
<td><strong>μ</strong></td>
<td></td>
<td></td>
<td>37.6</td>
</tr>
<tr>
<td>Heifer calves</td>
<td>kg.</td>
<td>kg.</td>
<td>kg.</td>
<td>units</td>
</tr>
<tr>
<td>Hereford</td>
<td>34.3</td>
<td>36.4**</td>
<td>0.846</td>
<td>207.9</td>
</tr>
<tr>
<td>Angus</td>
<td>33.4</td>
<td>33.9</td>
<td>0.870</td>
<td>211.7</td>
</tr>
<tr>
<td>Charolais</td>
<td>39.3</td>
<td>36.8**</td>
<td>0.925</td>
<td>228.8</td>
</tr>
<tr>
<td></td>
<td><strong>μ</strong></td>
<td></td>
<td></td>
<td>35.7</td>
</tr>
</tbody>
</table>

*Scores of 71-85 represent the choice feeder grade.

**General means from least-squares analyses.

P<.05 and **P<.01 refer to statistical significance of the difference in performance of a breed as sires and as dams.

The Charolais breed ranked highest of the three beef breeds in birthweight and preweaning growth, as indicated by both breed-of-sire and breed-of-dam means. This is interpreted to indicate relatively good growth potential and maternal ability. Relative growth superiority of Charolais cattle was also indicated in the reports of Damon et al. (1959), Klosterman et al. (1965) and Sagebiel et al. (1967a, increased somewhat, while residual mean squares for all other traits decreased in size.

Breed-of-Sire and Breed-of-Dam Effects. The least-squares means for breed of sire and breed of dam by sex-of-calf classes are shown in table 3. These means were obtained from the analyses from which the data for progeny of Brown Swiss females were excluded. The means contain the \( \mu + \hat{s}_i \) and \( \mu + \hat{d}_j \) terms described previously. The average performance of the breeds as straightbreds and in crosses is included in these effects. Differences in progeny performance between breed-of-sire and breed-of-dam classes within each beef breed were calculated. Standard errors of the differences were computed, and the differences were subjected to the standard t test (table 3).

Breed-of-sire effects on all traits observed in both sexes were highly significant, and the same was true in most cases for breed-of-dam effects (table 2). The means in table 3 indicate where the breed differences occurred. The information in these two tables offers relative comparisons of the three beef breeds as represented by the sires and dams contributing to this study.

The Charolais breed ranked highest of the three beef breeds in birthweight and preweaning growth, as indicated by both breed-of-sire and breed-of-dam means. This is interpreted to indicate relatively good growth potential and maternal ability. Relative growth superiority of Charolais cattle was also indicated in the reports of Damon et al. (1959), Klosterman et al. (1965) and Sagebiel et al. (1967a,
b). The Charolais, as breed of dam (table 3), ranked highest of the beef breeds in weaning score of calves, but the Charolais, as breed of sire, ranked second to the Angus in this trait and essentially the same as the Hereford breed. The Charolais as breed of sire produced heavier (P<.01) calves at birth than did the Charolais as breed of dam. Conversely, the Charolais as breed of dam produced the faster gaining calves of both sexes, although significant growth advantage was shown only by the male calves. Both male and female calves from Charolais dams also scored significantly (P<.01 and P<.05, respectively) higher at weaning than did calves by Charolais sires.

The Hereford breed ranked second to the Charolais in birthweight of calves by both breed of sire and breed of dam. On the other hand, the Angus, as both breed of sire and breed of dam, ranked second to the Charolais in preweaning gain and weaning weight of calves. Differences between the Angus and Charolais breeds in these postnatal growth traits were, however, consistently much greater than differences between the Angus and Hereford breeds. Relative ranking of the Hereford and Angus breeds on birthweight of calves by breed of sire and breed of dam, as well as ranking on preweaning gain and weaning weight by breed of dam, is reasonably well supported by results from other sources (Da-mon et al., 1959; Gregory et al., 1965; Gaines et al., 1966). Contrary to the present study, the results of the authors cited indicate that Herefords equalled or excelled Angus in preweaning gain and weaning weight as breed of sire. There were few significant differences between breed-of-sire and breed-of-dam classes within either the Hereford or Angus breeds in the present study (table 3).

**Heterosis.** The least-squares means for straightbreds and all possible first-cross combinations among the Hereford, Angus and Charolais breeds are shown by sex classes in tables 4 and 5. The means were computed from the least-squares constants as \( \hat{\mu} + \hat{s}_i + \hat{d}_j + (sd)_{ij} \). Also included in tables 4 and 5 are the mid-parent averages, the difference between each cross and mid-parent average, the percent advantage for each cross and the same type of information with all crosses combined. The standard errors of the differences between cross and mid-parent averages were computed and subjected to the standard t test. The level of significance of the differences is shown in the tables.

Heterotic effects on birthweight, preweaning gain, weaning weight and weaning score averaged higher for steers (table 4) than for heifers (table 5), and over-all differences between crossbreds and mid-parents were significant only for steers. Gregory et al. (1965), in a study involving the Hereford, Angus and Shorthorn breeds, reported nonsignificantly higher heterotic effects in heifers than in steers. Brinks et al. (1967), who studied crosses of inbred Hereford lines, reported higher heterotic effects on preweaning and weaning traits of heifer calves than on the same traits of bull calves.

The percentage of heterosis estimated for each trait in the present study compares favorably with the range of percentages indicated by reports of other investigators (Klosterman et al., 1965; Sagebiel et al., 1967a; Gregory et al., 1965; Gaines et al., 1966). The first source provided estimates of heterosis in all of the growth traits through weaning from crossing the Hereford and Charolais breeds. The second source provided an estimate for birthweight based on first-crosses among the aforesaid breeds and the Angus breed. The last two sources provided estimates for the growth traits through weaning and weaning score, based on crosses among the Hereford, Angus and Shorthorn breeds. The range of estimates from the sources cited, with data on male and female calves combined, were about 0 to 3.0%, 1.7 to 4.8%, 2.1 to 4.6% and 0 to 1.6% for birthweight, daily gain from birth to weaning, weaning weight and weaning score, respectively. In the present study, estimates for steer calves were near the upper limit of each range and the estimates for heifer calves were near the lower limit of each range. A heterosis estimate of 5.7% for weaning weight of heifer calves, based on crosses of the Hereford, Angus and Charolais breeds (Sagebiel et al., 1967b), was well above the range of other estimates cited.

Of the six crosses among the Hereford, Angus and Charolais breeds, few showed evidence of significant heterotic effects on birthweights (tables 4 and 5). Several negative values were obtained. Only the C X H cross showed significant (P<.01) heterotic effect on the birthweight of both steer and heifer calves. Differences between the C X H cross and the reciprocal cross also were significant (P<.01) for birthweight in both sexes. The C X A heifers were heavier (P<.05) at birth than the A X C heifers. All other differences in birthweights between reciprocal crosses were nonsignificant.
### TABLE 4. LEAST-SQUARES MEANS FOR STEER CALVES BY BREED-OF-SIRE x BREED-OF-DAM GROUPS

<table>
<thead>
<tr>
<th>Breed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Birthweight</th>
<th>Av. daily gain birth to weaning</th>
<th>205-day weaning wt.</th>
<th>Weaning score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sire Dam</td>
<td>Mean Mid-parent</td>
<td>Difference&lt;sup&gt;b&lt;/sup&gt; Cross average</td>
<td>Mean Mid-parent</td>
<td>Difference&lt;sup&gt;b&lt;/sup&gt; Cross average</td>
</tr>
<tr>
<td>kg.</td>
<td>kg.</td>
<td>%</td>
<td>kg.</td>
<td>kg.</td>
</tr>
<tr>
<td>H H</td>
<td>33.3</td>
<td>...</td>
<td>...</td>
<td>0.800</td>
</tr>
<tr>
<td>A A</td>
<td>32.0</td>
<td>...</td>
<td>...</td>
<td>0.860</td>
</tr>
<tr>
<td>C A</td>
<td>42.3</td>
<td>...</td>
<td>...</td>
<td>1.029</td>
</tr>
<tr>
<td>H H</td>
<td>35.4</td>
<td>33.6</td>
<td>1.8</td>
<td>5.4</td>
</tr>
<tr>
<td>A A</td>
<td>33.6</td>
<td>...</td>
<td>...</td>
<td>0.873</td>
</tr>
<tr>
<td>C H</td>
<td>37.6</td>
<td>38.8</td>
<td>-1.2</td>
<td>-3.1</td>
</tr>
<tr>
<td>A H</td>
<td>41.6</td>
<td>38.8</td>
<td>4.8**</td>
<td>13.4</td>
</tr>
<tr>
<td>C H</td>
<td>37.3</td>
<td>37.2</td>
<td>-0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>A C</td>
<td>38.9</td>
<td>37.2</td>
<td>1.7</td>
<td>4.6</td>
</tr>
<tr>
<td>All breed crosses</td>
<td>38.1</td>
<td>36.5</td>
<td>1.6**</td>
<td>4.4</td>
</tr>
</tbody>
</table>

<sup>a</sup> Hereford, Angus and Charolais are H, A and C, respectively. When specific crosses are designated in this paper (H x A for example), the breed of sire is always mentioned first.

<sup>b</sup> Cross minus mid-parent.

*P<.05

**P<.01

### TABLE 5. LEAST-SQUARES MEANS FOR HEIFERS CALVES BY BREED-OF-SIRE x BREED-OF-DAM GROUPS

<table>
<thead>
<tr>
<th>Breed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Birthweight</th>
<th>Av. daily gain birth to weaning</th>
<th>205-day weaning wt.</th>
<th>Weaning score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sire Dam</td>
<td>Mean Mid-parent</td>
<td>Difference&lt;sup&gt;b&lt;/sup&gt; Cross average</td>
<td>Mean Mid-parent</td>
<td>Difference&lt;sup&gt;b&lt;/sup&gt; Cross average</td>
</tr>
<tr>
<td>kg.</td>
<td>kg.</td>
<td>%</td>
<td>kg.</td>
<td>kg.</td>
</tr>
<tr>
<td>H H</td>
<td>34.6</td>
<td>...</td>
<td>...</td>
<td>0.797</td>
</tr>
<tr>
<td>A A</td>
<td>31.6</td>
<td>...</td>
<td>...</td>
<td>0.834</td>
</tr>
<tr>
<td>H H</td>
<td>39.7</td>
<td>...</td>
<td>...</td>
<td>0.977</td>
</tr>
<tr>
<td>A H</td>
<td>32.6</td>
<td>33.1</td>
<td>-0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>C A</td>
<td>38.8</td>
<td>33.1</td>
<td>0.7</td>
<td>2.1</td>
</tr>
<tr>
<td>H C</td>
<td>35.8</td>
<td>37.2</td>
<td>-1.4</td>
<td>3.8</td>
</tr>
<tr>
<td>C H</td>
<td>40.7</td>
<td>37.2</td>
<td>3.5**</td>
<td>9.4</td>
</tr>
<tr>
<td>H A</td>
<td>34.8</td>
<td>35.6</td>
<td>-0.8</td>
<td>-2.2</td>
</tr>
<tr>
<td>A C</td>
<td>37.4</td>
<td>35.6</td>
<td>1.8</td>
<td>5.1</td>
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<tr>
<td>All breed crosses</td>
<td>35.8</td>
<td>35.6</td>
<td>0.5</td>
<td>1.4</td>
</tr>
</tbody>
</table>

<sup>a</sup> Hereford, Angus and Charolais are H, A and C, respectively. When specific crosses are designated in this paper (H x A for example), the breed of sire is always mentioned first.

<sup>b</sup> Cross minus mid-parent.

*P<.05

**P<.01
Significant \((P<.01 \text{ to } P<.05)\) heterotic effects on preweaning daily gains of steers were obtained for only three of the six crosses, and there were no significant heterotic effects on preweaning daily gains of heifers. As in the case of birthweight, mean gains for some of the crosses were below the mid-parent averages. Steer gains for the \(H \times C\) and \(A \times C\) crosses were significantly \((P<.05 \text{ and } P<.01, \text{ respectively})\) higher than the gains for the reciprocal crosses. These were the only significant differences in daily gains between reciprocal crosses.

Significant \((P<.05 \text{ to } P<.01)\) heterotic effects on weaning weights of steers were indicated for four of the six crosses, and the mean gain was below the mid-parent average for the \(C \times A\) cross only. There were no significant heterotic effects on weaning weight of heifers. The \(A \times C\) steers were heavier \((P<.05)\) at weaning than the \(C \times A\) steers, and this was the only significant difference between reciprocal crosses.

Only the \(C \times A\) cross failed to show a significant heterotic effect on weaning score of steers. Conversely, only one cross, the \(A \times C\) cross, did show a significant heterotic effect on weaning score of heifers. Nearly all mean scores were, however, equal to or above the mid-parent averages. Both steers and heifers of the \(A \times C\) cross scored higher \((P<.01 \text{ and } P<.05, \text{ respectively})\) than those of the \(C \times A\) cross, but all other differences between reciprocal crosses were nonsignificant.

As represented by the breed samples used in this experiment, the Charolais breed exceeded the British breeds in all growth traits, while the Angus breed exceeded the Hereford and Charolais in weaning score. Crosses involving the Charolais breed resulted in the heaviest calves at birth and weaning. The best performing crossbred calves were obtained by breeding Charolais bulls with Brown Swiss females. The resulting calves, when the sexes are considered collectively, exceeded all other crossbred groups in preweaning gain and weaning weight and most nearly equaled the average gain and weight of the straightbred Charolais. These calves also exceeded the straightbred Angus calves somewhat in weaning score. In addition, the average birthweight of these calves was moderate, being essentially uninfluenced by heterosis.

Contrary to the results obtained by Gregory et al. (1965) and Gaines et al. (1966), the differences between the reciprocal crosses of the Hereford and Angus breeds were nonsignificant. These earlier workers reported the \(H \times A\) cross significantly superior to the \(A \times H\) cross for preweaning gain and weaning weight. Gregory et al. (1965) also found this to be true for weaning score. On the other hand, the present study and the two earlier studies all showed at least some heterotic effect of the \(H \times A\) and \(A \times H\) crosses on weaning weight. Damon et al. (1961) obtained no weaning weight advantage from crossing the Hereford and Angus breeds. It seems reasonable that differences in breed samples among studies and differences in environments under which the breeds were required to perform might be among the factors contributing to the inconsistencies noted.

**Performance of Brown Swiss Dams in Crosses.** Results of this section of the crossbreeding study are summarized in table 6. Means for the growth traits and score of calves produced by mating Brown Swiss cows to Hereford, Angus and Charolais bulls are presented in the table. Means for calves obtained by crossing beef X beef breeds may be obtained by summing the means and the appropriate deviations (table 6) with signs of the deviations reversed. The means were computed from the least-squares constants as \(\hat{\mu}+\hat{s}_1+\hat{a}_j+(\hat{sd})_i\). Statistical significance of the differences between specific crosses was determined by the standard \(t\) test.

The crossbred progeny from Brown Swiss cows mated to Hereford, Angus and Charolais bulls are compared first. Differences between the \(H \times B\) and \(A \times B\) crosses were all nonsignificant. The \(C \times B\) cross resulted in heavier \((P<.01)\) birthweights, tended toward faster gains thereafter and generally resulted in heavier weaning weights than the \(H \times B\) or \(A \times B\) crosses. Weaning scores for all of the crosses of beef bulls with Brown Swiss females were much alike.

Each of the remaining comparisons (table 6) is between Brown Swiss females and females of a beef breed when both were mated to the same bulls of a given beef breed. The \(H \times B\) cross resulted in faster gains after birth and heavier \((P<.01)\) weaning weights than either the \(H \times A\) or \(H \times C\) crosses. The \(H \times B\) calves were, in most cases, significantly heavier at birth, also. Differences in scores among these three crosses were of little practical importance, even though the difference between \(H \times B\) and \(H \times C\) steers was significant \((P<.05)\).

The \(A \times B\) cross was superior to \(A \times H\) for all growth traits \((P<.01)\). The \(A \times B\) cross
TABLE 6. PERFORMANCE OF BROWN SWISS DAMS AND DAMS OF THE BEEF BREEDS IN CROSSES WITH SIRES OF THE BEEF BREEDS

<table>
<thead>
<tr>
<th>Cross or comparison</th>
<th>Birthweight</th>
<th>ADG birth to weaning</th>
<th>205-day weaning wt.</th>
<th>Weaning score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M F</td>
<td>M F</td>
<td>M F</td>
<td></td>
</tr>
<tr>
<td>Sire Dam Sire Dam</td>
<td>kg.</td>
<td>kg.</td>
<td>kg.</td>
<td>units</td>
</tr>
<tr>
<td>H B</td>
<td>39.9 38.7</td>
<td>1.083 0.998</td>
<td>261.8 243.5</td>
<td>78.6 79.0</td>
</tr>
<tr>
<td>A B</td>
<td>41.1 40.6</td>
<td>1.025 0.984</td>
<td>251.0 242.5</td>
<td>78.4 77.6</td>
</tr>
<tr>
<td>C B</td>
<td>50.9 48.0</td>
<td>1.100 1.048</td>
<td>276.2 262.9</td>
<td>77.6 78.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparisons</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H B minus A</td>
<td>-1.2 -1.9</td>
<td>0.058 0.014</td>
<td>10.8 1.3</td>
<td>0.1 1.4</td>
</tr>
<tr>
<td>H B minus C</td>
<td>-11.0** -9.3**</td>
<td>-0.017 -0.050</td>
<td>-14.3 -19.3*</td>
<td>1.0 1.0</td>
</tr>
<tr>
<td>A B minus C</td>
<td>-9.8** -7.4**</td>
<td>-0.075* -0.064</td>
<td>-25.2** -20.6*</td>
<td>0.8 -4.4</td>
</tr>
<tr>
<td>H B minus H</td>
<td>4.1** 6.3**</td>
<td>0.186** 0.164**</td>
<td>42.3** 40.5**</td>
<td>-1.3 0.0</td>
</tr>
<tr>
<td>H B minus C</td>
<td>1.9 3.1</td>
<td>0.107** 0.092**</td>
<td>23.9** 22.1**</td>
<td>-2.1* -6.0</td>
</tr>
<tr>
<td>A B minus A</td>
<td>4.4** 6.9**</td>
<td>0.146** 0.135**</td>
<td>34.3** 34.6**</td>
<td>-1.7* -2.1*</td>
</tr>
<tr>
<td>A B minus C</td>
<td>3.5* 5.9**</td>
<td>0.013 0.057</td>
<td>6.1 17.5*</td>
<td>-4.4** -3.8**</td>
</tr>
<tr>
<td>C B minus C</td>
<td>6.9** 7.3**</td>
<td>0.186** 0.167**</td>
<td>45.0** 41.6**</td>
<td>-2.1* -9.0</td>
</tr>
<tr>
<td>C B minus A</td>
<td>11.5** 10.8**</td>
<td>0.187** 0.138**</td>
<td>49.8** 39.0**</td>
<td>-2.0* -1.6</td>
</tr>
</tbody>
</table>

| a H: Hereford, A: Angus, C: Charolais and B: Brown Swiss.  
| b Scores of 71-85 represent the choice feeder grade.  
| c M: steers, F: heifers.  
| d P<.05 and ** P<.01 refer to statistical significance of the difference between crosses.  

Results of this section of the study suggest that the relative growth superiority in crossbred calves from beef X Brown Swiss matings was due, at least in part, to a favorable maternal environment provided by the Brown Swiss dams. This interpretation is, of course based on the presumption that heterotic effects from crossing Brown Swiss with beef breeds is similar to heterotic effects from crossing the beef breeds among themselves. Preliminary information on postweaning traits, when the calves were no longer under the direct influence of the dams, suggests similarity in heterosis for these two types of crosses (Pahnish, 1966).

Heavy birthweights of calves from Brown Swiss females seems to have been associated somewhat with relatively large skeletal size of these females. Although skeletal measurements were not taken, differences between bodyweights of Brown Swiss dams and dams of the beef breeds are interpreted to be somewhat indicative of differences in skeletal size. On the average, dams of all breeds were of similar age, but the Brown Swiss dams were not as heavily muscled and were not as high in condition as those of the beef breeds when the weights were taken. About 3 weeks prior to the calving season over the 4-yr. period, the average weight of pregnant Brown Swiss females (574 kg.) exceeded the weights of the Hereford, Angus and Charolais females by 56, 82 and 32 kg., respectively. Average weight of Brown Swiss cows after the calves were weaned in the fall (549 kg.) exceeded the weights of Hereford, Angus and Charolais cows by about 42, 68 and 21 kg., respectively. The relationships of cow weights to calf weights will be covered in another report.

It appears that a relatively high level of milk production by Brown Swiss dams contributed to the superiority in preweaning gains.
CROSSING BEEF AND DAIRY BREEDS

of their crossbred calves over crossbred calves from dams of the beef breeds. The volume of milk supplied by Brown Swiss dams was not, however, in excess of the amount that the calves could consume.

Dams of the beef breeds showed an average advantage of 2.3 and 1.5 units in weaning score of steer and heifer calves, respectively, over Brown Swiss dams. Any depression of weaning score associated with Brown Swiss breeding was, however, of small practical importance, as the mean score of all breeding groups compared were within the middle to high choice feeder grade.

Summary

Data collected at the U. S. Range Livestock Experiment Station, Miles City, Montana, on 244 male calves and 254 heifer calves were used to estimate the amount of heterosis resulting from crossing beef cattle breeds. Cattle of the Hereford, Angus and Charolais breeds were mated to produce straightbred calves of each breed and all possible two-breed combinations in each of the years 1962 through 1965. In conjunction with the main study, 54 male calves and 34 heifer calves were used to compare Brown Swiss dams with dams of the three beef breeds as producers of crossbred calves. To produce beef X Brown Swiss calves, the Hereford, Angus and Charolais sires used in the main study were also mated, in each breeding season, with Brown Swiss females.

Steer calves exhibited more heterosis for each of the observed traits than did heifer calves. For each trait, the over-all advantage of crossbreds over mid-parent average was significant for steer calves and nonsignificant for heifer calves. Heterosis for birthweight, preweaning daily gain, weaning weight and weaning score amounted to 4.4, 3.7, 3.8 and 2.2% for steer calves and 1.4, 2.0, 1.9 and 0.4% for heifer calves, respectively.

The heaviest weights and greatest daily gains were exhibited by the progeny of the Brown Swiss dams. The average advantage shown by Brown Swiss dams over dams of the three beef breeds for steer and heifer calves, respectively, was 5.4 and 6.7 kg. for birthweight, 0.138 and 0.126 kg. for preweaning daily gain and 33.6 and 32.5 kg. for weaning weight. Conversely, dams of the beef breeds showed an average advantage of 2.3 and 1.5 units in weaning score of steer and heifer calves, respectively, over Brown Swiss dams. Average scores of all breed groups were, however, within the middle to high choice feeder grade.

Literature Cited