Breeding and Genetics

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On the cover: An alert and attentive herd sire checks his domain. Careful attention to bull selection is critical, as he provides half the genetics for the calves from the cows with which he is mated.
Table of Contents

Topic                                                                 Page
Better breeding produces more profitable beef...........................................1
Traits to consider when selecting cattle................................................2
  Consider traits of both the individual and relatives, Breed associations print EPDs
Purebred producer’s responsibility ..........................................................3
Four ways to make genetic improvements................................................3
  Heritability estimates, Selection differential, Genetic correlations, Generation interval
Selection and management of the herd bull ..............................................4
  Use performance evaluations, Computing a performance ratio, Examine reproductive organs
  Missouri Frame Score
Managing herd bulls..................................................................................6
Pedigree........................................................................................................6
Selecting replacement heifers.....................................................................7
  Reproductive performance, Maternal ability, Growth rate, Efficiency of gain, Carcass desirability
Tips for selecting replacement heifers from your herd..............................10
Crossbreeding for better beef cattle performance....................................10
  Decisions concerning crossbreeding
What is heterosis?........................................................................................13
Crossbreeding data......................................................................................14
  Explanation of crossbreeding terms, Two-breed backcross or crisscross systems,
  Three-breed terminal crossing system, Two-breed terminal cross plus terminal crossbreeding system
  Three-breed crossbreeding system, Rotation breeding system
Does crossbreeding have an adverse effect on the purebreed industry?.......16
Selection criteria for crossbreeding............................................................16
Breed traits of economic importance.........................................................16
Evaluating a herd’s performance................................................................17

Tables
Table 1. Heritability estimates for economic traits in beef cattle
  indicate potential progress that can be made by selection..........................3
Missouri Frame Score..................................................................................7
Table 2. Five-year summary to weaning, Missouri Heterosis Project...............11
Breeding and Genetics

Beef cattle production in Missouri and in the United States is a segmented industry composed of purebred breeders, commercial producers, cattle feeders, packers and retailers.

Although they all play different roles, their ultimate goal is the same: All strive to create and market a more efficiently produced product that is acceptable to consumers.

To raise beef that fulfills these two goals takes a thorough knowledge of feeding, disease control, marketing, management and — as discussed in this section — breeding and genetics.

There are two approaches a cattle producer should use to upgrade a breeding program. One is to improve herd health and nutrition. The other is to genetically improve the herd by selecting quality breeding stock and making the best use of a herd's genetic potential.

Genetics and breeding play a bigger role than the actual cattle breed does in producing a quality beef product. There is no breed today that is superior in all economically important traits. Most breeds excel in one or more traits. Breeders must recognize the traits that distinguish their breed and capitalize on them. At the same time, they should select for other traits to improve the breed's performance.

Better breeding produces more profitable beef

The annual Performance Tested Bull Sale at the University of Missouri-Columbia gives cattle producers a chance to buy sires based on performance data.
The beef cattle industry has gone through several cycles of breed selection since the turn of the century. In the last 10 years, most breeders have been selecting animals to improve traits associated with performance and economic value.

Several types of information are available to help you select animals for the herd. The most useful information is from performance records from within a herd. Traits that are highly heritable, such as rate of gain, carcass traits and yearling weight should be measured on each animal.

Information on relatives such as sire, dam, half-siblings and progeny also can be used. This information is most useful when animals are selected at an early age, before their performance is known. It is also useful in selecting for traits that are expressed only in one sex, for traits that are low in heritability and to gather carcass information.

Most breed associations print a sire evaluation summary of Estimated Progeny Differences (EPDs) for calving ease, weaning weight and yearling weight with associated accuracy values. These factors should receive attention when you select animals. The EPD is the estimated performance of the bull's progeny for a given trait, relative to other bulls in the breed. For example, a bull with an EPD of +20 for weaning weight would be expected to sire calves that average 10 pounds more at weaning than calves from a bull with an EPD of +10. The accuracy values are a measure of the confidence you can place in the EPD. A bull that has an EPD with an accuracy near 1 is unlikely to change in the future. If the accuracy is much lower than 1, perhaps 0.6 to 0.7, the future EPD may improve or worsen as more information becomes available on the bull.

Most breed sire summaries are similar and give needed information for a breeder to stack pedigrees for a potential young sire.
The purebred breeder or seedstock producer should possess a working knowledge of genetics along with an appreciation of all traits of economic importance to the beef industry. The breeder should also understand the procedure for measuring or evaluating differences in these traits. Because purebred breeders are the architects of the industry, the breeder must be able to develop an effective breeding program to bring about genetic change.

The term "selection" in beef cattle simply means letting superior animals produce more offspring than inferior animals. The improvement expected in herd performance for a given trait will depend on how effective the breeder's selection is in changing gene frequency (increasing the frequency of a desired gene and decreasing the frequency of an undesirable gene for a given trait).

For example, an animal that is superior for growth rate will have a greater number of desirable genes for growth than will an animal having a slower growth rate. Important characteristics should be measured and recorded to help sort genetically superior animals for breeding purposes.

Researchers in animal breeding have developed tools to improve beef cattle. These tools are: heritability estimates, selection differential, genetic correlation and generation interval. If performance information is known on the selected parents, these tools can predict the progress of a specific trait with a high degree of accuracy.

Heritability estimates show how well a specific trait can be transmitted to offspring (See table 1). Heritability values differ for each trait and range from 0 to 100 percent. The larger the heritability, the more genetic improvement possible. Gene frequency for traits with high heritability can be changed faster than frequency for traits with low heritability.

<table>
<thead>
<tr>
<th>Traits</th>
<th>% Heritable</th>
<th>Traits</th>
<th>% Heritable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertility</td>
<td>10</td>
<td>Efficiency of Gain in Feedlot</td>
<td>40</td>
</tr>
<tr>
<td>Birth Weight</td>
<td>40</td>
<td>Slaughter Grade</td>
<td>45</td>
</tr>
<tr>
<td>Cow Maternal Ability</td>
<td>40</td>
<td>Dressing Percent</td>
<td>45</td>
</tr>
<tr>
<td>Pre-weaning Gain</td>
<td>40</td>
<td>Carcass Grade</td>
<td>45</td>
</tr>
<tr>
<td>Weaning Weight</td>
<td>30</td>
<td>Backfat Thickness</td>
<td>40</td>
</tr>
<tr>
<td>Conformation Score Weaning</td>
<td>30</td>
<td>Loin Eye Area</td>
<td>70</td>
</tr>
<tr>
<td>Post-Weaning Gain in Feedlot</td>
<td>57</td>
<td>Tenderness</td>
<td>60</td>
</tr>
<tr>
<td>Post-Weaning Gain in Pasture</td>
<td>45</td>
<td>Retail Yield</td>
<td>60</td>
</tr>
<tr>
<td>Yearling Weight</td>
<td>60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Selection differential or "reach" is the difference between the statistical average of an animal's trait, such as rate of gain, and the average of the existing herd. The higher the selection differential, the larger the expected improvement in the herd. Selection differential is affected mainly by the number of animals used from the original herd as replacements. For example, as more heifers from the herd are used as replace-
Genetic correlations

Genetic correlations refer to the genetic association between two or more traits caused by the same genes affecting both traits or being carried on the same chromosome. These correlation values can vary from -1 to +1. A positive correlation indicates that two traits will increase together. A negative correlation indicates that genetic antagonism occurs: Selecting for one of the traits will reduce the other. Correlations near 0 indicate that two traits are nearly independent of each other. Selection for one trait will have little or no effect on the other.

Generation interval

The generation interval is the herd's turnover rate. It is equal to the average age of all parents when progeny are born. In general, the shorter the generation interval, the more likely a specific trait will genetically improve over a long period of time. The average generation interval in most beef cattle herds is 5 to 7 years.

However, heaviest calf weaning weights are obtained from cows that are from 5 to 10 years of age. Therefore, the commercial producer may want to take advantage of the higher productivity of older cows, even though this slows the genetic change within the herd.

Selection and management of the herd bull

Herd sire selection is the most important decision a breeder will make. Buying a bull is a sizable investment, and that investment has the most influence on the economic return from the herd for years to come, especially if his daughters are kept as herd replacements.

The bull has two major functions in the herd. One is to settle a high percentage of cows in a relatively short time. The other is to sire calves with genetic potential for rapid, efficient growth and desirable carcasses.

Use performance evaluations

It is difficult to visually determine how fast and efficiently a beef animal will gain weight in a feedlot. Bulls should be performance-tested under the same conditions in which you expect their progeny to perform. This helps identify undesirable traits, such as animals that stop growing and become overtly fat in the feedlot or animals that are susceptible to ailments such as founder or bloat.

Individual performance records can eliminate much guesswork as you select a herd sire. Pay close attention to the bull's pedigree, EPD and adjusted 365-day weight. Also, compare his weight to other bulls in the herd during his first year (weight ratios). Select a bull that has above-average ratios at weaning, at 205-day weight, post-weaning gain and adjusted 365-day weight.

To calculate ratios, compute the average performance of a test group for a specific trait and divide this average into the individual bull's performance for that trait. A 365-day weight ratio is figured in the following example on page 5.

Only 30 to 35 percent of a bull's weaning weight superiority is passed on to his progeny. However, 50 to 60 percent of his weight as a yearling (365-day weight) should be passed on to his calves. This means that a
We have 10 young bulls being fed alike in a lot to compare their performance. We want a figure (ratio) for each to compare the weight of each bull at one year old.

Average weight for the 10 bulls at 365 days = 1,100 lbs.

Weight of bull No. 1 = 1,200 lbs.

\[
\text{Ratio} = \frac{1200}{1100} \times 100 = 109, \text{the ratio for bull No. 1.}
\]

Bull's superiority is better determined at 365 days than at 205 days of age.

The actual yearling weight should be used with caution. If the British breeds are fed under practical management conditions, they should weigh about 1,000 pounds. Under similar conditions, the larger breeds should weigh about 1,200 pounds. However, one should look at the weight ratio within a group rather than compare weights between herds. Two bulls with the same genetic potential may vary 200 pounds or more just because they were fed and managed in different environments.

While the commercial producer considers weight and production efficiency to be the most important traits, the purebred breeder also selects animals based on visual appraisal of muscling, structural soundness, masculinity and frame. These traits are important for longevity and reproductive efficiency.

Muscling is observed by evaluating the forearm, rump, round and, especially, the center of the round at the stifle.

The herd bull should have structurally sound feet and legs if he is to be used in large breeding pastures on rough terrain.

The height at the shoulders is a better measure of size than is weight, which is influenced by fat content. Data from Missouri and else-

Performance records eliminate guesswork as you select a herd sire. Pay close attention to the bull's pedigree, EPD, adjusted 356-day weight and his weight ratio.
where indicate that within a bull management group, each inch of additional height from weaning to 1 year of age will give a bull about 30 pounds additional weight.

**Examine reproductive organs**

The reproductive organs, both internal and external, should be examined by a veterinarian for abnormalities and diseases. Both testicles should be of normal size and consistency. There is a direct relationship between testicular size and sperm production. Watch for bulls with monorchidism and cryptorchidism (one or both testicles retained inside the body cavity) and scrotal hernias. Both conditions are inherited and impair reproductive performance.

All bulls should have a semen evaluation prior to breeding to eliminate questionable breeders. Surveys show that 10 to 15 percent of bulls tested are unsatisfactory as potential breeders. This evaluation gives you more assurance that the bull will settle a high percentage of the fertile cows, and it will help determine the potential breeding status of bulls for sale or purchase.

**Missouri Frame Score**

The Missouri Frame Score is a valuable measurement of frame and is used to predict an animal's size at maturity. The shaded columns of the chart on page 7 show the three commonly used adjustment ages: weaning, yearling and 18 months.

**Managing herd bulls**

Herd bulls are athletes during the breeding season. It is important that they stay in good physical condition.

During the breeding season, observe the bull often for abnormalities. Record the breeding dates of a few cows and check 18 to 23 days later to see if those cows return to heat. Each delayed heat period will cost about 40 pounds of calf weight for each cow recycling.

The recommended number of cows per bull varies with the bull's age, number of bulls per pasture and pasture size. A good rule of thumb for a 90- to 120-day breeding season is 30 to 35 cows per mature bull; 20 to 25 cows per bull that is less than 2 years old.

If more than one bull is being used for breeding cows in pastures in a commercial operation, rotate half of the bulls in and out of the pastures during the first half of the breeding season. The nutritional requirements for growing and maintaining herd bulls are discussed in MU publication M151, *Beef Cow/Calf: Nutrition*.

**Pedigree**

A record of a bull's ancestry is important to a breeder of registered cattle. Although it is of lesser importance to commercial producers, they should not ignore the pedigree in the event of a genetic defect. Remember, only the closest relatives should receive much consideration when using pedigree information. Performance information from close relatives, especially carcass data from steer progeny and mothering ability of daughters, is very useful in selecting a sire. Pedigree also will help detect genetic abnormalities such as dwarfism and double muscling.
### Missouri Frame Score

<table>
<thead>
<tr>
<th>Age in months</th>
<th>Frame 1</th>
<th>Frame 2</th>
<th>Frame 3</th>
<th>Frame 4</th>
<th>Frame 5</th>
<th>Frame 6</th>
<th>Frame 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-6</td>
<td>32-33</td>
<td>34-35</td>
<td>36-37</td>
<td>38-39</td>
<td>40-41</td>
<td>42-43</td>
<td>44-45</td>
</tr>
<tr>
<td>7-8</td>
<td>39.75-40.5</td>
<td>41.5-41.75</td>
<td>42.25-42.5</td>
<td>42.75-43</td>
<td>44-44.5</td>
<td>44.75-45</td>
<td>45-45.5</td>
</tr>
<tr>
<td>9-10</td>
<td>41.75-42.5</td>
<td>43.5-43.3</td>
<td>44.25-44.5</td>
<td>45-45.5</td>
<td>46-46.5</td>
<td>46.75-47.5</td>
<td>47-47.5</td>
</tr>
<tr>
<td>11-12</td>
<td>43-43.5</td>
<td>44.75-45</td>
<td>45.75-46.5</td>
<td>46.75-47</td>
<td>47-47.5</td>
<td>47.75-48.5</td>
<td>48-48.5</td>
</tr>
<tr>
<td>13-14</td>
<td>44.5-45</td>
<td>45.75-46.5</td>
<td>46.75-47</td>
<td>47-47.5</td>
<td>48-48.5</td>
<td>48.75-49</td>
<td>49-49.5</td>
</tr>
<tr>
<td>15-16</td>
<td>45-45.5</td>
<td>46-46.5</td>
<td>47-47.5</td>
<td>48-48.75</td>
<td>49-50</td>
<td>49.75-50.5</td>
<td>50-51</td>
</tr>
<tr>
<td>17-18</td>
<td>45.5-46.5</td>
<td>46.5-47.5</td>
<td>47-47.5</td>
<td>48-48.75</td>
<td>49-50</td>
<td>50-50.5</td>
<td>51-51.5</td>
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<tr>
<td>19-20</td>
<td>46-46.5</td>
<td>47-47.5</td>
<td>47.5-48.5</td>
<td>48-48.75</td>
<td>49-50</td>
<td>50-50.5</td>
<td>51-51.5</td>
</tr>
<tr>
<td>21-22</td>
<td>46.5-47.5</td>
<td>47-47.5</td>
<td>47.5-48.5</td>
<td>48-48.75</td>
<td>49-50</td>
<td>50-50.5</td>
<td>51-51.5</td>
</tr>
<tr>
<td>23-24</td>
<td>47-47.5</td>
<td>47.5-48.5</td>
<td>48-48.75</td>
<td>48.75-49</td>
<td>49-50</td>
<td>50-50.5</td>
<td>51-51.5</td>
</tr>
</tbody>
</table>

1. Frame 3 is average for British breeds.
2. Frame 5 is average for Continental breeds.

Height measurement is taken over the shoulder at the fifth rib or elbow.

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Production records and visual appraisals are essential when selecting top heifers. Breeders should select traits that have economic importance to the industry and that are heritable. The major traits to consider are: reproductive performance, maternal ability, growth rate to slaughter, rate of gain, longevity, carcass composition and desirability.

Fertility is extremely important from an economic standpoint, but fertility traits have a heritability of only 10 to 15 percent. Genetic improvement of these traits through animal selection is slow. But economics dictate that open and late-breeding cows should usually be culled. You should also improve the environmental factors that affect reproduction, such as nutrition, disease control and management.

A calf’s birth weight can also affect a cow’s reproductive performance. Dystocia, or calving difficulty, is influenced by many other factors, including pelvic area, the sire’s breed and the nutrition of the cow. To avoid this problem, producers should carefully consider breed, cow size, sire and average birth weight for that breed. Your goal should be to produce a calf with a birth weight average of 7 to 9 percent of mature cow weight. Use a lower value for heifers and a higher value for mature cows. Once you have obtained this level of performance, select sires within a +2 pounds EPD or -2 pounds EPD for birth weight to minimize calving difficulty within comparable physiological mature-size breeds.

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Selecting replacement heifers

Reproductive performance
Maternal ability

Maternal ability is the largest single factor influencing a calf’s weaning weight (which is 30 percent heritable). The Most Probable Producing Ability (MPPA) is a measure of maternal ability. MPPA reflects the cow's milk production and the growth rate of the calf, which is measured by the weaning weight of her calf.

Breeders should strive to increase a cow’s milk production to maximize weaning weight. The sire also must be considered in this equation. If your replacement heifers are selected from his progeny, he should be from a cow with outstanding maternal ability.

Maternal EPD is an estimate of a sire's ability to transmit maternal performance as expressed in daughter’s first-calf weaning weight. Some breed associations report EPDs for milk and weaning growth but not maternal EPD. This value can be obtained by taking one-half of a bull's EPD for weaning weight and adding it to the milk EPD. To estimate the milk EPD, subtract one-half of the weaning EPD from the maternal EPD.

Growth rate

Growth rates are about 30 to 60 percent heritable. To determine growth rates, measure the animal's weight at birth, weaning and yearling ages. Also, measure daily gains in the feedlot and record the animal’s rate-of-gain.

To increase the overall growth rate of a herd, replacement heifers and potential sires should be selected on the basis of weaning weight and their 12-month or 18-month weight ratio. This selection will improve feed efficiency, maternal ability and carcass cutability of the herd.

Post-weaning growth rate is influenced by feed efficiency. It is also highly associated with phases in the calf’s growth curve from birth to maturity.

EPD for growth at weaning and yearling weight are the two most important economic traits in beef production after you have a live calf on the ground. Remember, beef is sold by the pound. Select for weaning weight EPD above +15 pounds and yearling EPD above +45 pounds to improve profitability within breed selection. But remember: There are
breed differences for size. In a crossbreeding program, you may want to restrict selection for high-growth EPDs because birth, weaning and yearling weight are all positively related. Selection of sires with high-growth EPDs from large breeds may result in an unacceptably high incidence of calving difficulty.

Feed efficiency is the amount of feed required to produce a unit of gain. Gross differences in feed requirements per unit of gain in either live or carcass weight depend upon many factors: feed type, environmental conditions, live weight, body composition and health.

Research reveals rather large differences in feed requirements per unit of live weight gain when observed both within and between breeds and types. The data usually indicate the larger mature-weight cattle breeds gain faster with more efficient live-weight gains compared to the smaller breeds when evaluated over a reasonably constant age or weight range.

Studies comparing British breeds with muscular, fast-growing continental European straightbred breeds or their crosses have consistently shown the latter to have more efficient live-weight gains under controlled feeding. Studies from the USDA Meat Animal Research Center indicate that the fast-growing breed types and their crosses had less fat at the end of the feeding period.

Cundiff (1970) summarized feed efficiency and found that heterosis, or hybrid vigor, had little or no effect on feed efficiency.

Several researchers have reported that there is reasonably high heritability in an animal's feed requirement per unit of live-weight gain within a breed. Most of these studies have been on free-choice feed regimes, however. This makes it difficult or impossible to determine whether these "easy keepers" truly gain weight more efficiently or if they ate more feed than needed to meet maintenance requirements.

To produce the highest slaughter weight with the minimum feed, you should emphasize three things: the animal's ability to consume feed at high levels, its ability to use net energy consumption to produce high amounts of salable beef and its ability to reach an optimum mature size.

Regardless of its efficiency or inefficiency of maintenance, the animal that consumes feed only at a level sufficient to maintain body weight is worthless as a meat producer.

Studies show that feed consumption is from 43 percent to 77 percent heritable. The more feed consumed, the greater the net energy available to produce salable beef.

Carcass desirability refers mainly to carcass cutability and carcass quality or grade. Selecting animals for both of these traits is effective because these traits have moderate to high heritability. Emphasis should be placed on progeny testing sires for carcass desirability. There is a negative association between cutability and carcass quality. To make progress in both traits, you should select different breeds or individuals within a breed that will produce the best average performance for these traits.

In most cases, accuracy values are low for carcass EPD and are not often used. This doesn't mean the traits are unimportant. It means the information is expensive to acquire.
Tips for selecting replacement heifers from your herd

Usually, not more than 50 percent of the heifers of a herd are saved for replacements. To get away from the extremely fat heifers, consider placing emphasis on frame or height at the shoulder as well as weight.

Replacement heifers can be selected based on their adjusted 205-day weaning weight ratio. British breed heifers should weigh at least 450 to 500 pounds at 205 days if they are to calve as 2-year-olds. The larger breeds should be about 100 pounds heavier at 205 days. Replacement heifers of British breeds should gain about a pound a day during the first winter following weaning, weigh about 650 to 700 pounds at breeding, gain another 200 to 250 pounds during gestation and weigh somewhere around 900 to 950 pounds at calving. The larger breeds would be about 100 pounds heavier than British breeds at calving.

Selecting for early sexual development can be accomplished by exposing a greater number of heifers than are needed as replacements, then only breeding them for 30 to 45 days. This practice will allow selection for fertility as well as maturity.

Creep feeding replacement heifers is not recommended prior to weaning. Creep feeding will mask the milk production ability of the dam and prevent accurate selection for this trait in the heifer calves. If the heifers are creep fed, the ration should be formulated so that they do not become too fat.

The purebred and commercial producer should also select for replacement heifer traits that will contribute to a long, productive cow life.

This includes selection for:
- Structurally sound feet and legs.
- Frame or skeletal size, as indicated by height at the shoulders, which is associated with long bodies. Most commercial cows should have a Missouri Frame Score from 4 to 6.
- Adequate muscling in the forearm and stifle. Don’t select heifers with abnormally heavy muscling.
- Heifers with well-developed sex organs and udders.
- Heifers that are relatively free of excess fat or wastiness in the brisket, flanks and udder.

Crossbreeding for better beef cattle performance

A great deal of interest in crossbreeding has developed in recent years. You should look objectively at crossbreeding and consider all advantages and disadvantages before deciding whether or not it is economical and suitable to your resources.

Crossbreeding has little effect on the highly heritable economic traits. Therefore, superior performance-tested bulls are as much a key to a crossbreeding program as they are to a commercial straightbred program or to a purebred operation.

Research at stations with both systems has shown an advantage to using crossbred females. For example, in a five-year study at Spickard, Mo., crossbreds out-performed purebreds in all traits compared (see Table 2).

Research at Fort Robinson, Neb., and at the U.S. Meat Animal Research Center in Clay Center, Neb., indicates that at least 21 percent more pounds of calf per cow exposed could be weaned from crossbred
cows in a three-breed cross than in straightbreds. This is due to:
- Early puberty and conception as heifers.
- Reduced postpartum interval.
- Increased first estrus conception.
- Lower embryonic mortality.
- Reduced calf death losses from birth to weaning.
- Faster calf growth rate.
- Greater longevity of the crossbred cow.

In addition, crossbreeding allows the commercial producer to combine the desirable traits of two or more breeds to give a better overall end product.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Avg. All 2-Breed Crosses</th>
<th>Avg. All Purebreds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fetal deaths (%)</td>
<td>4.87</td>
<td>5.82</td>
</tr>
<tr>
<td>Cows calved (%)</td>
<td>84.58</td>
<td>80.50</td>
</tr>
<tr>
<td>Cows weaned calves (%)</td>
<td>78.23</td>
<td>76.57</td>
</tr>
<tr>
<td>Weaning weight (lbs.)</td>
<td>383.09</td>
<td>373.60</td>
</tr>
<tr>
<td>Weaning type score (pts.)</td>
<td>9.96</td>
<td>9.97</td>
</tr>
<tr>
<td>Ibs. of calf weaned/cows bred</td>
<td>323.86</td>
<td>298.45</td>
</tr>
<tr>
<td>Ibs. of calf weaned/100 lbs. of cow</td>
<td>42.25</td>
<td>42.10</td>
</tr>
<tr>
<td>Ibs. of calf weaned/100 lbs. of metabolic cow wt. @ 0.75 power</td>
<td>22.09</td>
<td>21.51</td>
</tr>
</tbody>
</table>

Table 2.
Five-year summary to weaning, Missouri Heterosis Project. Averages for purebred and crosses.
Crossbreeding enhances heterosis, genetically improving herd performance.

The commercial herd producer faces several major decisions about crossbreeding. Ask yourself:

- Should I produce two-breed or three-breed crossbred calves?
- Which breeds should I use and in what order or rotation?
- What are strengths and weaknesses of the breeds?
- What breeds are most readily available in my area?
- Should I use exotic breeds?
- Should I use dairy breeds?
- Is the cross I choose accepted in local markets?
- Should I raise my own replacements or should I buy them?
- Should I use artificial insemination?

The size of your cow herd will influence the type of crossbreeding program to follow. For example, a herd owner may decide to produce three-breed crossbred calves from a herd of 30 cows. This will be relatively easy if the owner buys crossbred F1 females, breeds them to a bull of a third breed and keeps no replacement heifers. About 100 percent of the maximum heterosis advantages will be obtained.

If you decide to keep your replacement heifers, however, you will need at least two breeds of bulls on hand at the same time. If you want to start with straightbred females and produce three-breed cross calves, you will eventually have three breeds of bulls on hand at the same time. The latter is feasible with a large cow herd but is not practical with 30 cows.

The two-breed rotational cross is probably the easiest program for the commercial producer who plans to keep replacement heifers and
who will start with straightbred females. This crossbreeding program produces about 67 percent of the maximum heterosis advantages. You can follow this program by using a bull of breed B on cows of breed A; heifers from this cross are bred back to a bull of breed A. The heifers from the latter mating are bred to bulls of breed B, and so on.

Crossbreeding allows the producer to increase the pounds of calf weaned per cow and to do so at a lower cost. It is important, however, to choose breeds that complement one another.

For example, Hereford and Angus cows are medium in size and milk production. The 2- and 3-year-old cows could be used in a two-breed rotational cross and replacement heifers could be saved for these matings. The older cows could be mated to bulls of a larger third breed to increase calf growth potential. All calves, whether steers or heifers, would be marketed from this three-breed cross.

Remember, hybrid vigor is important in traits that have low heritability, such as reproduction and maternal traits. Research has shown that crossbreeding increases the number of calves born, reduces losses and increases calf weaning weight.

There are other factors to consider when choosing breeds for a crossbreeding program. Whenever possible, cows should be matched to their environment in terms of feed requirements, milk production and forage production. The quality and quantity of feed available during the calving and breeding season should dictate cow size and milk production.

Heterosis is the percentage change in the crossbred offspring as compared to the average of two parent breeds.

**Heterosis example, using weaning weights**

Breed A = 400 lbs.  
Breed B = 500 lbs.

Average A + B = 450 lbs.

Offspring A x B = 475 lbs. or +25 lbs.

\[
\frac{25}{450} = 5.5\% \text{ heterosis}
\]

**Heterosis values reported for some of the traits in a two-breed cross of British breeds:**

- Calving percent = 1.5 percent.
- Calf livability = 3.0 percent.
- Percent calf crop = 4.1 percent.
- Weaning weight = 4.9 percent.
- Feedlot gain = 2.4 to 6.5 percent.
- Feed efficiency = 0.7 percent.
- Carcass traits = 0.
- Sexual maturity = 35 to 41 days earlier.

**Heterosis values reported for crossbred dams mated to a third breed:**

- Calf crop raised = 4.7 percent.
- Weaning weight = 5.6 percent.
- lbs. of beef/cow exposed = 20 to 25 percent.

What is heterosis?
Crossbreeding data

Heifers from cross $F_1$ AB are backcrossed on sire B and then those BAB heifers are mated to sire A, continuously crisscrossing. Heifer BA is mated to sire A as a backcross. Heifers from this mating are then mated back to sire B as crisscross mating.

This system can be managed with two pastures and natural mating for multiples of 50 to 80 cows. The two-breed cross gives about 67 percent heterosis if dominance is the basis of heterosis. This assumes that recombination effects are negligible in offsprings from crossbreed dams.

Explanation of crossbreeding terms

- **$F_1$** — The first cross between two unrelated genetic lines or purebreds is called $F_1$.
- **$F_2$** — The $F_2$ is a cross between $F_1$s. Most of the heterosis is lost and this cross is not recommended.

**Two-breed backcross or crisscross systems**

- **Backcross** — This is a breeding scheme where the $F_1$ is mated back to one of the parent breeds or lines.
- **Crisscross** — This is a two-breed rotational systematic backcross, mating the crossbred female back to the breed that sired her dam (see Figure 1).

**Three-breed terminal crossing system**

In a three-breed terminal crossing system, the producer raises or purchases $F_1$ females with desirable maternal and carcass traits. They are bred to a growthy, top-cross sire of a third breed. All offspring are marketed; no replacements are kept.

**Two-breed terminal cross plus terminal crossbreeding system**

Two breeds are used in a crisscross to produce replacements for a terminal crossbreeding system with practically zero selection pressure on the female side for growth. As each cow produces a replacement, she is moved to the terminal phase of the program at about 4 years of age and

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Figure 1.
**Two-breed crisscross or backcross system.**

Figure 2.
**Rotaterminal with three breeds (two-breed crisscross plus terminal crossing system).**

Expect 72 percent heterosis in offspring and 56 percent heterosis in dam.
is bred to a growth-breed sire. She remains there for her productive life and all her progeny are marketed as slaughter animals. No replacement females are kept in the "terminal" phase.

This system lends itself to heavy milking breeds because replacements are kept from young cows that haven't reached potential milk production to affect subsequent milk production of their daughters. Mature cows are used with terminal sires because they have less calving difficulty with the larger calves. One of the big keys to this system, then, is to use superior production-tested sires in the crisscross phase as well as in the terminal phase because all selection pressure will have to come from sire selection (See Figure 2).

The three-breed crossbreeding system uses a two-breed crisscross or backcross to produce females to be mated to growth-breed terminal sires. This system requires at least three pastures and is adapted to herds of 100 cows or more. Progeny in two-fifths of the herd crisscross line will give 67 percent heterosis with limited calving difficulty. Three-fifths of the cows will go in the terminal line as mature cows with limited calving difficulty, making maximum use of genetic germplasm reach and giving 100 percent of heterosis potential. Use sires from a performance-tested herd since the cow lines will be closed.

A rotation breeding system involves three or more breeds in a systematic rotation with females retained from these crosses. The three-breed rotation will give about 87 percent of the heterosis benefits.

The four-breed cross will most closely maximize heterosis without overlapping generations because of cow life in a herd if sire breeds are rotated every two or three years (see Figure 3).

This system will be effective with 75 to 120 cows, or multiples, or with three-producer herds using natural mating. This system gives about 20 percent more heterosis than the two-breed crisscross or backcross system. The maximum potential heterosis in this system is approximately 87 percent. Standard crossbreeding systems are most effective when used with large herds of cattle. Several systems have been developed especially for small herds using only one or two bulls.

The key to this system is finding three complementary breeds. For more information, see MU publication G2040, Crossbreeding Systems for Small Herds of Beef Cattle. To order publications, please see the directions given on the back cover of this manual.
Does crossbreeding have an adverse effect on the purebred industry?

No, it strengthens the industry. Crossbreeding is based on combining gene pools or breeds for an initial response at different phases of the system. Permanent improvement of economic traits still must come from selection within purebreds or specific selected sire lines of non-purebreds.

A non-purebred, performance-tested, specific, selected sire line might be produced if the purebred industry became complacent in testing and selecting for those traits that have the greatest impact on the economy of the beef industry. But as long as purebred breeders remain conscientious about economic aspects of their breeds, this is not likely to occur.

Selection criteria for crossbreeding

The selection criteria in crossbreeding are the same as in the purebred industry. That is, if you select the highest-performing animal for a given trait, then mate the best to the best, you will combine complementary abilities, plus gain the heterosis advantage.

Two mediocre parents combined give a mediocre crossbred offspring, except for the heterosis effect.

What should you consider in selecting breeds for crosses?

- Select breeds that are superior for traits that will give greatest economic return.
- Plan choice of breeds that will give the greatest selection differential for specific traits.
- Use breeds that are the least related to give maximum heterosis response.
- Use breeds that are acceptable to your buyers.
- Use breeds that will maximize profit from your resources.

Breed traits of economic importance

Yearling Weight. The average yearling weight should be about 450 to 500 pounds greater than the respective weaning weight.

Cow Herd Mature Weight. To just maintain present average cow weight in the herd, you should select bulls that have a mature weight of about 1.6 times the average weight of the cows. To increase the future weight average of the cow herd, use bulls that have a mature weight of at least 1.7 times or more than average cow weight.

Average mature cow weights of 1,150 pounds or less are usually found in the Angus, Polled Hereford, Hereford, Shorthorn and Jersey breeds.

Breeds that range from 1,100 to 1,400 pounds are Brahman, Brangus, Santa Gertrudis, Holstein, Limousin, Brown Swiss, Beefmaster, Charolais, Simmental, Gelbvieh and Beef Friesian.

Maine Anjou and Chianina mature cow weights usually average 1,400 pounds or more.

Carcass Quality. Angus and Jersey yield the highest-quality carcass grade but usually have slightly lower total yield of retail cuts.

The other British breeds, Polled Hereford, Hereford and Shorthorn, are considered intermediate in quality grade and yield. The other breeds discussed will have high-select to low-choice carcass grades but higher yield grades than British breeds.
Milk Production. The breeds with below-average milk production are Angus, Beefmaster, Brahman, Brangus, Charolais, Chianina, Hereford, Polled Hereford, Santa Gertrudis and Shorthorn.

Those with intermediate milk production are Gelbvieh, Beef Friesian and Maine Anjou, and those with high milk production are Simmental, Holstein, Jersey and Brown Swiss.

Birth Weight. Breeds with average birth weights of 75 pounds or less on the average are Angus, Shorthorn and Jersey. Breeds with birth weights of 70 to 80 pounds are Polled Hereford, Hereford, Brangus, Brahman, Santa Gertrudis, Beefmaster and Limousin. Breeds with birth weights of 80 to 95 pounds are Charolais, Simmental, Gelbvieh, Chianina, Holstein and Brown Swiss.

Weaning Weight. Breeds with weaning weight averages (no creep) of less than 500 pounds are Angus, Polled Hereford, Hereford, Shorthorn and Limousin. The breeds with weaning weight averages of 500 to 600 pounds are Charolais, Gelbvieh, Santa Gertrudis, Brahman, Brangus, Chianina, and Jersey; while Simmental, Holstein, Beef Friesian, Brown Swiss and Maine Anjou average more than 600 pounds at weaning.

Not all of these breeds and crosses are adapted to a given production system. The commercial or purebred breeder must select a breed or breed combination to make the most of his resources.

A major objective of all beef cattle breeders, whether purebred or commercial, should be to increase the genetic producing ability of each cow in the herd. This contributes a higher economic return to the producer and to the beef industry. The major purpose of individual beef cattle performance testing records is to measure differences, such as weaning weight, frame and yearling weight between individual animals within the same herd and under the same environmental conditions. Figure 4 illustrates those traits that are evaluated in the Missouri on-the-farm Beef Cattle Data Performance Testing Program, MU publication MP474, Missouri Beef Cattle Improvement Programs, On-The-Farm Performance Testing. To order this publication, see information on the back cover of this manual.

The economic genetic differences that are medium to highly heritable in beef cattle are why purebred breeders are in business. If there were no differences, heritability would be 0 and there would be no market for highly superior or outstanding purebred animals. These differences will exist between cows within the same herd, progeny within the same herd and sires used within the same herd.

All cow-herd owners should participate in a beef performance testing program. Production records, if well-kept, can be a useful tool to (1) help measure herd productivity, (2) evaluate bull performance, (3) identify high-producing cows, (4) help cull low-producing cows, (5) identify differences in gaining ability of calves and yearlings, (6) provide permanent annual records, (7) select herd replacements, and (8) aid in management decisions and reproductive efficiency.

The Missouri beef cattle performance testing program was developed to provide herd owners with information that will help them select and cull cattle and to improve the production of their cow herds.
Production records help cattle producers evaluate their herd's productivity and make needed improvements.

The Missouri beef cattle improvement program is conducted in the state by area extension livestock specialists with the help of state livestock specialists. Detailed information on the program, including the Missouri beef performance resting program publication and the necessary work sheets, can be obtained at a county Extension center.

All national breed associations also have performance evaluation programs to assist cattle producers in identifying genetically superior cattle. Contact the breed association office for more information.

The challenge to both purebred and commercial breeders is to breed cattle with genetic merit and utility. This challenge can be met only by dedicated breeders who are willing to use every tool of science at their disposal, to evaluate and systematically record each animal's superiority or inferiority.
Missouri Beef Cattle Improvement Programs
BEEF CATTLE DATA Entry Record Form

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1 Complete only if actual birthweights are taken.

Figure 4. Sample of herd improvement record from Missouri Beef Cattle Improvement Programs, MU publication MP474.