Chapter 4

ANIMAL BREEDING

Improving production efficiency and product desirability through each segment of the beef cattle industry rests with purebred breeders and commercial cattle producers. They determine the matings that produce beef and replenish breeding stock. Therefore, they should have a working knowledge of genetics, or the science of heredity, an appreciation of the traits of economic importance throughout the beef cattle industry and an understanding of the procedures for measuring or evaluating differences in these traits.

Basis for Genetic Improvement

Differences among animals result from the hereditary differences transmitted by their parents and the environmental differences in which they are developed. With minor exceptions, each animal receives half its inheritance from its sire and half from its dam. Units of inheritance are known as genes which are carried on threadlike material present in all cells of the body called chromosomes. Cattle have 30 pairs of chromosomes. The chromosomes and genes are paired with each gene being located at a particular place on a specific chromosome pair. Thousands of pairs of genes exist in each animal, and one member of each pair in an animal comes from each parent.

Tissue in the ovaries and the testicles produces the reproductive cells, which contain only one member of each chromosome pair. The gene from each pair going to each reproductive cell is purely a matter of chance.

The female is born with all of her potential eggs already produced and stored in the ovaries. Once she reaches puberty, one egg, sometimes two, will be released from the ovaries during each estrous cycle throughout the remainder of her reproductive life. The male, on the other hand, does not produce sperm cells until he reaches puberty. Sperm are then produced in the testicles by a process that requires about 60 days. Because beef cattle have 30 pairs of chromosomes and only one chromosome from each pair is contained in each sperm cell, there are 1.1 billion different combinations of chromosomes that may be contained in the sperm cells.

When a reproductive cell, or sperm cell, from a male fertilizes a reproductive cell, or egg, from the female, the full complement of genes is restored. Some reproductive cells will contain more desirable genes for economically important traits than will others. The union of reproductive cells that contain a high proportion of desirable genes for economically important traits results in a superior individual and offers the opportunity for selection. However, the chance segregation in the production of reproductive cells and recombination upon fertilization results in the possibility of genetic differences among offspring of the same parents.

The genetic merit of a large number of offspring will average that of their parents. However, some individuals will be genetically superior to the average of their parents and others will be inferior. Those that are superior, if selected as parents of the next generation, contribute to improvement.

Factors Affecting Rate of Improvement from Selection

Factors that affect rate of improvement from selection include (1) heritability [h^2], (2) selection differential [SD], (3) genetic correlation or association among traits and (4) generation interval [GI]. The amount of improvement for a single trait may be calculated as Rate of Improvement = (h^2 x SD) ÷ GI. If selection is based on more than one trait, the genetic association between traits becomes important.

Heritability

Heritability is the proportion of the differences between animals that is transmitted to the offspring. Thus, the higher the heritability for any trait, the greater the possible rate of genetic improvement. When evaluating animals, every attempt should be made to subject all animals from which selections are made to as nearly the same environment as possible. This results in a large proportion of the noted differences among individuals being genetic and will increase the effectiveness of selection.

The average heritability levels for some of the economically important traits in beef cattle are presented in Table 5. The heritability of any trait can be expected to vary slightly in different herds depending on the genetic variability present and the uniformity of the environment. Based on heritability estimates, selection should be reasonably effective for most performance traits, but these traits vary in heritability and economic importance. Thus, the rate of expected improvement and the emphasis each trait should receive in a selection program will also vary considerably.

TABLE 5. Percent Heritability Levels for Various Traits	
Low (h^2 less than 20%)	
Twinning	3
Calf Survival Ability	5
Conception Rate	10
Calving Interval	10
Medium (h^2 20%-45%)	
Birth Weight	40
Gain Birth to Weaning	30
Weaning Weight	30
Feedlot Gain	45
Feed Efficiency	40
Pasture Gain	30
Conformation Score at Weaning	25
Yearling Body Length	40
Carcass Grade	40
Fat Thickness – 12th Rib	45
High (h^2 greater than 45%)	
Yearling Weight	50
Yearling Hip Height	60
Yearling Wither Height	50
Dressing Percentage	50
Ribeye Area	70
Mature Weight	60

The heritability estimates for each trait combined with the trait's economic value to that particular cattle producer should determine the relative emphasis each trait receives in the selection program. If a trait is medium to high in heritability, the purebred producer may select animals that are superior in that trait and expect reasonable progress to be made toward the goal. If the trait is low in heritability, little progress will be made by selection; however, considerable improvement may be made in traits with low heritabilities by utilizing crossbreeding. Thus, a commercial producer benefits in traits (primarily reproductive traits) that are low in heritability by crossbreeding while improving traits that are medium to high in heritability by purchasing bulls from a purebred producer who has been selecting for improvement in those traits.

Selection Differential

Selection differential is the difference between selected individuals and the average of all animals from which they were selected. For example, if the average weaning weight of a herd is 450 pounds and those selected for breeding average 480 pounds, the selection differential is 30 pounds. The average cattle producer who produces their own replacements saves from 30 to 40 percent of the heifers each year while retaining only 2 to 5 percent of the bull calves. Because of these differences in replacement rates, the greatest selection differential will be on the bull's side. Up to 90 percent of the genetic improvement in a trait over four generations is due to the sire used. Every effort should be made to obtain the maximum selection differential possible for the trait or traits of greatest economic importance and highest heritability, ignoring traits that have little bearing on either efficiency of production or carcass merit.

Genetic Association Among Traits

A genetic relationship among traits is the result of genes favorable for the expression of one trait tending to be either favorable or unfavorable for the expression of another trait. Genetic associations may be either positive or negative. If the genetic association between two traits is positive as is the case between birth weight, pre-weaning gain, post-weaning gain and eventual mature size, then selection to increase one of these traits would also cause some increase in the other traits. When two traits are negatively correlated, such as rate of gain and carcass quality, selection to increase one will cause the other trait to decrease.

Generation Interval

The fourth major factor that influences rate of improvement from selection is the generation interval – that is, the average age of all parents when their progeny are born. Generation interval averages approximately 4 1/2 to 6 years in most beef cattle herds. Rate of progress is increased when the generation interval is shortened. This can be accomplished by vigorous culling of the cow herd based on their production, calving heifers as two-year-olds and using yearling bulls on a limited number of females.

Mating Systems

The five fundamental types of mating systems are (1) random mating, (2) inbreeding, (3) outbreeding, (4) assortative mating and (5) disassortative mating.

Random mating is mating individuals without regard to similarity of pedigree or similarity of performance.

Inbreeding is mating individuals that are more closely related than the average of the breed or population. Linebreeding is a special form of inbreeding and refers to the mating of individuals so the relationship to a particular individual is either maintained or increased. Linebreeding results in some inbreeding because related individuals must be mated.

Outbreeding is mating of individuals that are less closely related than the average of the breed or population. The term outcrossing is also used to mean outbreeding when matings are made within a breed. Crossbreeding is a form of outbreeding.

Assortative mating is the mating of individuals that are more alike in performance traits than the average of the herd or group. This mating system is often used when establishing uniformity within a herd.

Disassortative mating is the mating of individuals that are less alike in performance traits than the average of the herd or group. This mating system is used to correct deficiencies within a herd.

Crossbreeding for Commercial Beef Production

Crossbreeding can be used in commercial beef production to realize heterosis, or hybrid vigor, and complementary combinations of breed characteristics and to match market requirements, feed and other resources available in specific herds.

The effect of heterosis on some performance traits is important. Productivity in some traits is greater in crossbred animals than the average of the two parents due to heterosis. The effect of heterosis is inversely proportional to heritability. For example, high heritability traits such as post-weaning growth rates, feed efficiency and carcass composition are affected less by heterosis than low heritability traits such as livability and fertility.

More than 50 breeds are available in significant numbers to cattle producers through either natural breeding or artificial insemination. These breeds vary greatly in performance traits. Because offspring resulting from crossbreeding tend to be a blend of both parents, crossbreeding can be used to obtain a performance goal in one or two years that would require several years to accomplish through selection for genetic change within one breed.

Also, by matching the sire breed and the dam breed in proper combination, complementary traits can be obtained in the offspring through crossbreeding. For example, a cow selected for its small size, quick maturity, high fertility and low maintenance cost can be matched with a sire breed selected for faster growth rate and a lean muscular carcass.

Crossbreeding Systems

To properly use crossbreeding, a producer must plan the operation in advance and consider the cow herd size, potential herd size, facilities, available capital, potential market, level of management, etc., and then decide which system of crossbreeding and which breeds are best suited for the operation. The following are examples of systems which may be used.

Crisscross or Two-Breed Rotation

This is the simplest crossbreeding system (Figure 11). A crisscross is a two-breed rotation or systematic backcross involving only two breeds and two pastures (Table 6). The present herd of straightbred cows may be used as the base (Herd A). They are bred to a bull of a different breed selected to complement the cow herd breed. The crossbred, or F_1, heifers are saved as replacements for Herd B and bred to a bull of the same breed as the original cow herd. The straightbred cows of Herd A are gradually replaced by heifers produced in Herd B.

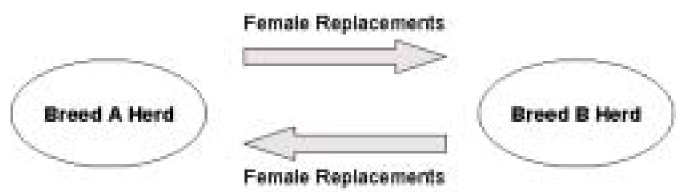

FIGURE 11. Crisscross or two-breed rotation.

The advantages are that this system (1) can be used by small producers, (2) is simple, (3) produces female replacements for the herd and (4) utilizes crossbred dams.

Disadvantages are (1) only 67 percent of potential hybrid vigor is achieved (Table 6) and (2) with natural service, two breeding pastures are required.

TABLE 6. Characteristics of Various Crossbreeding Systems

Mating System	Minimum Herd Size	Breeding Pastures*	Hetero-zygosity (Calf)	Hetero-zygosity (Cow)
Crisscross	50	2	67	67
Rotational	75	3	86	86
3 Breed Rotational	Any size	1**	100**	100**
Terminal Cross		3***	75***	50***
2 Breed Rotational with Terminal Sire	150	3	100	67

*Assures natural mating. **Only if F_1 females are purchased.
***Includes all animals in the system.

With the use of artificial insemination, the number of cows can be less than two bull units and only one breeding pasture would be required. In place of rotation, a producer with only one bull unit of cows may use bulls of Breed B for 5 to 6 years, and then change back to bulls of Breed A for the next 5 to 6 years. The bull must be replaced every 2 years to prevent sire-daughter matings. By changing sire breeds every 4 years, breeding replacement heifers to calve at two years of age and culling about 12 percent of the older cows each year, the highest concentration of one breed in any group of calves would be 75 percent as a result of a single backcross.

Rotational

This system requires three or more breeds of bulls with crossbred heifers saved from each sire breed (Figure 12). In this system, three herds or breeding groups are maintained (Table 6).

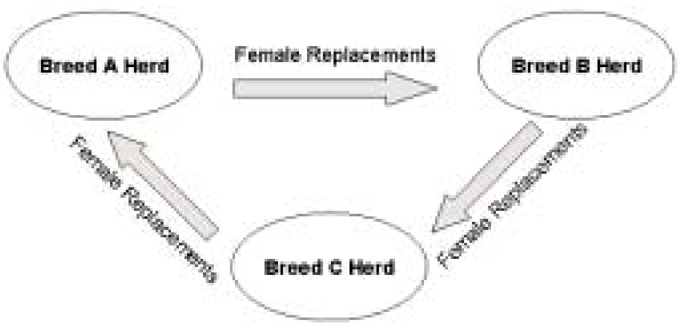

FIGURE 12. Rotational crossbreeding system.

The rotation starts by breeding the present cow herd (Herd A) to a bull of a different breed. Females produced in this herd are used as replacements for Herd B and bred to a bull of a second breed. Crossbred heifers from Herd B are used as replacements for Herd C. These heifers are then bred to a bull of a third breed (the same breed as the original cow herd). After this, rotation is continued with the same breeds of bulls.

The main advantages of the three-breed rotation system are (1) it maintains an 86 percent degree of hybrid vigor (Table 6), (2) female replacements are produced in the herds and (3) crossbred dams are utilized.

Disadvantages include the need for (1) large number of cows and cow herds, (2) three or more breeding pastures and (3) greater management skills.

Rotational crossbreeding may involve four, five or more breeds. With more breeds in a planned rotation, a slight increase in heterotic response can be obtained, but management becomes more difficult.

Terminal Cross

The terminal cross is not a self-perpetuating system like the crisscross or rotational systems. It requires the input of straightbred females into the system at some point. Figure 13 illustrates one method that can be used.

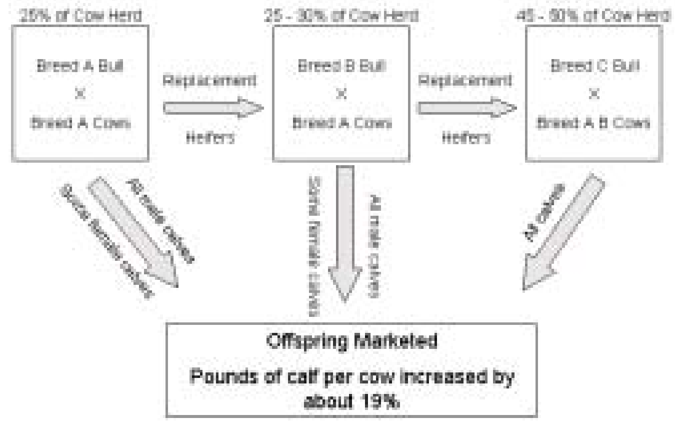

FIGURE 13. Terminal cross.

Herd A is maintained as straightbred cattle with replacement heifers being produced within the herd. Replacement heifers for Herd B are also produced by Herd A. Herd B females are mated to a bull of a second breed (B) to produce crossbred heifers (B X A). These crossbred females are then mated to a terminal sire (C) and all calves are marketed.

Advantages of this system are (1) maximum hybrid vigor in the F_1 female and terminal cross calf and (2) selection of breeds that complement each other.

Disadvantages are (1) a high percentage of straightbreds must be maintained to provide replacement heifers, (2) a large operation would be required for this system, (3) approximately 50 percent of the brood cows would be straightbred and (4) 20-25 percent of market calves would be straightbred.

This system may be modified so as to involve more than one producer. For example, one producer might produce the straightbreds with another producer completing the first and terminal cross. An individual producer may complete only the terminal cross by purchasing F_1 females and mating them to a bull of a third breed. However, these crossbred heifers may be hard to locate and high in price.

Combination Crisscross and Terminal Cross

Many modifications of the three systems mentioned previously are possible. For example, Figure 14 illustrates a program in which a crisscross and terminal cross are combined. In this program, Herds A and B would be used in a crisscross as illustrated in Figure 11. Replacement heifers would be produced from these two herds. Only the superior cows would be retained in these two herds. Older and poorer producing cows would be taken from Herds A and B and placed in Herd C. These would then be bred to a bull of a third breed for a terminal cross, and all calves from Herd C would be marketed. In this manner, a producer would take advantage of the terminal cross to maximize hybrid vigor without having to purchase female replacements from an outside source.

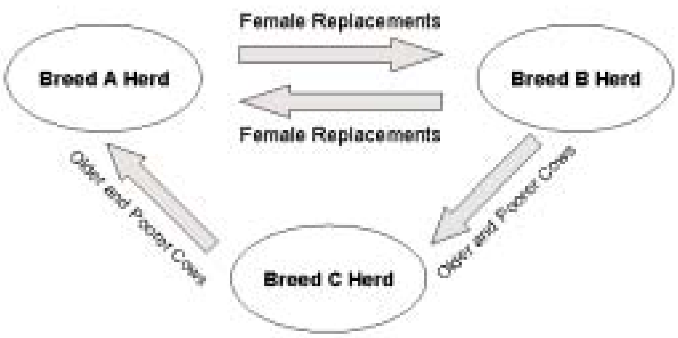

FIGURE 14. Combination crisscross-terminal system.

If 66 percent of the maximum heterotic response in the crisscross is realized, 100 percent in the terminal cross and if half of the total cows are in Herd C, we would expect this total system to realize approximately 83 percent of the potential hybrid vigor. This does not appear to be as useful as the three-breed rotational in terms of total response. However, in this system, cows can be selected for maternal traits and the third breed utilized in the terminal cross could be more specialized for growth and carcass characteristics without regard to maternal traits, which are important in the three-breed rotation. In other words, complementarity can be used to a much greater degree and, when combined with hybrid vigor, should provide a greater total response.

This system also provides some flexibility in altering herd size since Herd C can be reduced or enlarged without changing the basic crossing system.

Genetics and the Environment

In Arkansas, beef production requires compromise at intermediate levels among the traits of mature size, maturing rate and milk production in the cow herd, if best use of feed and forage resources on the farm are realized. These traits are factors that determine energy requirements. Feed and forage resources vary among farms; therefore, the optimum level of these characteristics must vary as well if the best choice of cattle is made to match the feed and forage resources. How well the cow herd matches the resources or how nearly the forage resources can meet the requirements of the cattle will be reflected in the supplementary feed that must be provided. Failure to provide needed supplementary feed for a cow herd that is mismatched with the forage resource will be reflected in increased ages at puberty, reduced reproduction and weaning rates and higher maintenance costs of cows. The size and maturing rate of the parents also influence carcass leanness and marbling at acceptable market weights.