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Texas Adapted Genetic Strategies for Beef Cattle

IV: Breeding Systems

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There are three steps in establishing a logical genetic strategy for beef production. First, determine the production and marketing conditions and match applicable levels of animal performance to these conditions. Second, choose a breeding system. Third, select genetic types, breeds, and individuals within breeds for compatibility with the first two considerations.

Beef cattle producers face two types of decisions concerning breeding systems—which animals are allowed to reproduce and which males are bred to which females.

Mating Plans

Mating plans can be based on: 1) randomness;2) genetic relationship (pedigree); or 3) performance or visual appearance (phenotype).

- **Random mating** does not mean random selection. Rather, individuals are selected for breeding. Then they may be managed in one breeding group, with one or multiple sires, or both males and females can be randomly gate-cut into separate breeding groups. Either way, there is no action taken to determine which animals mate. Random mating is a rather common procedure, especially for multiple-sire herds where it is difficult to maintain more than one breeding group.
- **Pedigree mating** implies that all individuals in a genetic population (such as a herd, family line, or breed) are related to some extent. One pedigree plan mates individuals more closely related than the average of the population; it is termed inbreeding. While long-term inbreeding in a closed herd may increase genetic uniformity, inbreeding usually reduces performance, especially in fertility and survival. This is called inbreeding depression. One type of inbreeding is linebreeding, which is used to concentrate the genetic influence of some line or individual while minimizing increases in inbreeding.

  Mating animals less related than average is called outbreeding or outcrossing. Outcrossing of lines within a breed can restore performance lost to inbreeding depression. Mating individuals of different breeds is called crossbreeding, which often increases performance above what might be expected from the parent breeds. This effect is called hybrid vigor or heterosis. It is commonly thought that outbreeding increases variability, but well-planned outcrossing or crossbreeding produces uniform progeny.
- **Phenotype mating** plans are based on performance or visual appearance, not pedigree, and are called assortative. Mating individuals most alike in performance or appearance is positive assortative mating such as mating the heaviest males to the heaviest females or the shortest males to the shortest females. Compared to random mating, this results in more variation in progeny, fewer progeny near average, and more extremes.

  This plan is used mainly in hopes of producing a few extreme animals to quickly change a population. Positive assortative mating is sometimes called "mating the best to the best," a sound concept if parents are superior in all important factors.

Examples of the opposite plan, negative assortative, are mating the heaviest males to the lightest females or the shortest males to the tallest females. Consequences of this scheme, compared to random mating, are decreased variation, more individuals near average, and fewer extremes. If population-average performance in offspring is optimum, then this plan is useful. Often these types of matings are used to correct problems. For example, in a herd with milk production levels too high for existing forage resources, sires of lower milking genetics would produce better adapted replacement heifers. Unless dramatic genetic change is needed, negative assortative mating often is a sound strategy.

Crossbreeding

Crossbreeding begins with the mating of two purebreeds. The term F_1 applies to progeny of such a cross. A more useful definition of F_1 is the progeny of parents with no common genetic background. The most desirable crossbreds are results of genetically superior purebred parents. In fact, superior purebreds may easily exceed the performance of crosses from mediocre purebred parents.

There are three benefits of crossbreeding over restriction to a single breed (straightbreeding)—heterosis, breed combination, and complementarity.

Heterosis

Heterosis is measured as performance of crossbred progeny compared to the average of purebred parents. Heterosis is usually positive. It is highest in the progeny of least related parents. For instance, there is greater heterosis in crossing the genetically dissimilar Hereford and Brahman breeds than in crossing the more similar Hereford and Angus.

Heterosis is reduced when the same breed is a constituent of both parents. As an example, if cattle sired by Angus and out of Hereford are bred back to one of these breeds (a backcross), the resulting offspring average 50 percent less heterosis than the F_1 Angus-Hereford. If the F_1 is bred instead to a third breed, then heterosis of progeny can be either higher, the same, or lower, depending on the genetic relationship of the third breed to Angus and Hereford. If, instead of a backcross, you mate two F_1s of the same breed makeup, the progeny, called F_2, also average 50 percent reduction of heterosis from the F_1, the same as a backcross. But if you intermate those F_2s, producing an F_3, there is no additional loss of heterosis, on the average, beyond that experienced in going from the F_1 to F_2. Heterosis is reduced beyond the F_3 only to the extent that inbreeding occurs.

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Characteristics differ in heterosis. Heterosis is highest in fitness traits such as fertility, livability, and longevity. It is intermediate in milk production, weight gain, feed efficiency, and body size. It is lowest in carcass traits. Heterosis is highest in factors affecting efficiency in dams.

Breed Combination

Even if heterosis was not a factor, there could be benefits merely from combining breeds with different characteristics to produce a superior package. For example, females with genetics for high carcass quality but small body size and low rate of gain could be mated to sires with genetics for large size and fast weight gain but low carcass quality, resulting in progeny acceptable in both growth and carcass quality. In many instances, favorable combinations are the most important benefit from crossbreeding.

Complementarity

The mating just discussed might be called complementary, as it combines parents with differing strengths and weaknesses to produce desirable progeny. However, what if the females in the example were as large in body size as could be efficiently maintained on that particular forage resource? The smaller body size of these females is an advantage for cow adaptability in this situation but a disadvantage in gaining ability of progeny. That disadvantage could be countered with large, fast-gaining sires. But the heifers from that mating would not be useful for replacements in that herd, as they would be too large in body size. The only way to exploit this mating in that environment is to continually use a particular genetic type of female and a different type of sire. This technique is called complementarity, and it is possible only with a particular breeding system, discussed below.

Types of Breeding Systems

There are two basic breeding systems. If the source of replacement females is heifers produced in the herd, there is a continuous system. If heifers are not put back in the herd, there is a terminal system. Differences in these systems must be well understood, or serious mistakes can be made.

Continuous

A continuous system produces its replacement females but requires an external infusion of sires (unless inbreeding is involved, and that is rarely desirable in commercial production). Since replacement females are retained in this system, the cowherd has genetics of both the sires and dams. Therefore, if sires have traits that are undesirable in brood cows, those traits cannot be hidden in a continuous system. Both sires and dams in continuous systems should be similar in important traits and without any undesirable characteristics. Genetic extremes generally are not compatible with continuous breeding systems.

Terminal

In a terminal system, both replacement females and sires must come from external sources; they are either purchased or come from another herd. However, since heifers produced in terminals are not retained for breeding, there is more flexibility in choice of genetic types. Specialized maternal and sire types can be used in terminals, since undesirable traits can be masked in a properly designed system.

A combination of relatively small dams bred to larger sires in a terminal system fully exploits complementarity. However, in some cases, breeds similar in body size also are useful for terminals as, for example, where climate favors females of heat-tolerant breeds, many of which are relatively low in carcass quality. Sires from breeds known for high carcass quality, most of which are no larger than medium in size, might be the best choice in this case. Some complementarity in body size and weight gain is given up for female adaptability.

Continuous Systems

Straightbreeding

Here the same breed of sire and dam is used continually, so progeny usually are rather uniform in appearance. Straightbreeding is particularly useful in producing parents for crossbreeding. The biggest shortcoming of commercial straightbreeding is the important lack of heterosis.

True Rotations

True rotation systems use two or more breeds and the same number of breeding groups. The simplest rotation is a two-breed, sometimes called a crisscross. A different breed of sire is used continually in each of the two breeding groups. Replacement heifers are moved or rotated for breeding from the group where they were produced to the other group, where they remain for all of their lifetime matings. Figure 1 shows a two-breed true rotation. In a rotation of three or more breeds, a heifer is placed in the breeding group with the breed of sire to which the heifer is least related. This ensures minimal loss of heterosis in progeny.

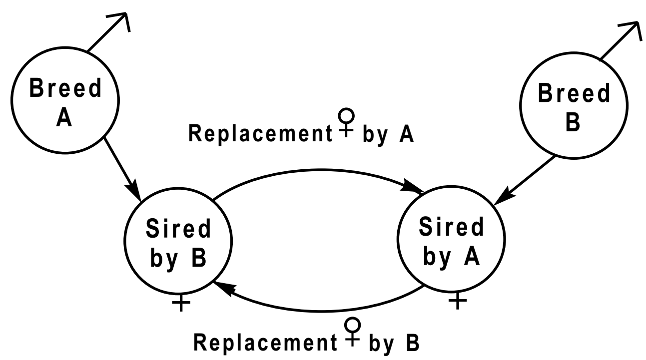

Figure 1. A two-breed true rotation.

Because they require multiple breeding groups, true rotations are rather complicated unless artificial insemination is used. (A. I. simplifies many of the mechanics of most crossbreeding systems.) Once a true rotation is fully in place, all breeding groups are present every year. Also, a compromise must be made between complementary matings and uniformity between groups. You cannot maximize both in rotations. Because of these complexities and limitations, true rotations are uncommon.

Sire Rotations

Sire rotations are sometimes called rotations in time. Instead of rotating females among multiple breeding groups as in true rotations, sire breeds are changed periodically in a single breeding group. A sire breed might be used for from one to several breeding seasons, most commonly for two or three. Ordinarily, a single breed of sire is used during a breeding season to produce more uniform progeny and simplify identification of the breed composition of potential replacement females.

Heterosis is lower in sire rotations than in true rotations, though the reduction is slight in well planned systems. Highest heterosis is maintained by keeping replacement heifers out of dams that are least related to the heifer's breed of sire. This merely requires identifying a dam's breed of sire, if a single breed of sire is used in a breeding season.

Sire rotations are much simpler to conduct than true rotations, because there is only one breeding group. This is one of the most common crossbreeding systems. Unfortunately, in many cases such plans are conducted haphazardly, with little thought given to a logical schedule.

Terminal Systems

Static Terminal

In a static terminal, replacement females must come from outside, either by purchase or from another herd. It is simplest to purchase replacement females because then only one breeding group is needed for the terminal cross. This is a particularly simple plan when purchases are limited to females that have calved at least once or twice, in which case there are no heifers that require separate facilities and easy-calving sires.

A straightbred terminal is mechanically possible, but there usually is no good reason to do so because the benefits of crossbreeding are absent. A possible exception is if a strong market exists for some straightbred and the breeder does not wish to or cannot develop heifers.

A two-breed static system, using straightbred males and sraightbred females of different breeds, produces heterosis in crossbred calves. However, such a system forfeits the considerable benefits of heterosis of crossbred dams.

A three-breed terminal is more efficient. It uses two-breed F_1 cows and a third breed of sire. First, straightbred females with desirable maternal traits are produced. Then these are crossed with another desirable maternal breed to produce the F_1. Then the F_1 females are used in a terminal cross. Figure 2 shows a three-breed static terminal system.

In a complete static system, about one-fourth of the females are straightbred, about one-fourth produce the F_1, and only about one-half of the females are in the terminal portion. Someone must perform all these functions in order for three-breed terminals to be possible, and this requires time and expense. The unique advantage of static terminal crossing is the opportunity to fully exploit complementarity. The main disadvantage is in the creation of replacement females.

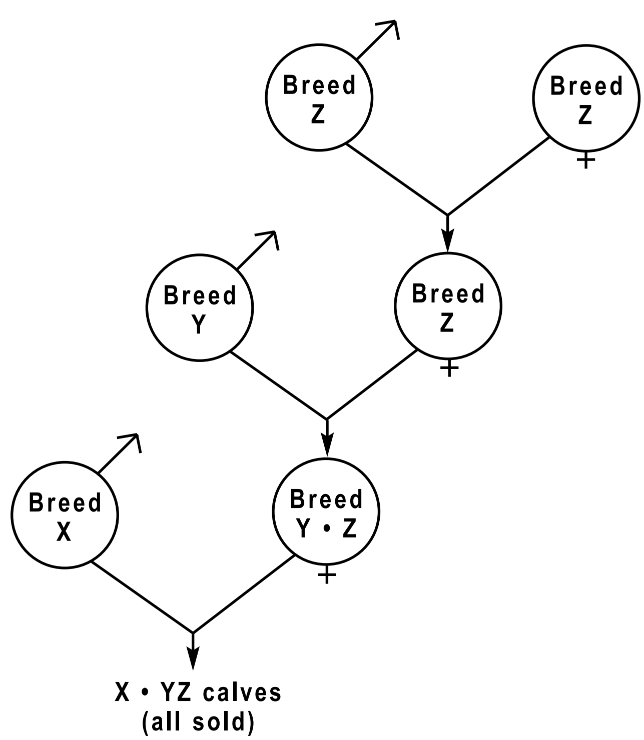

Figure 2. A three-breed static terminal.

Rotation Terminals

A rotation terminal (actually a combination of the two basic systems) is designed to solve some of the problems of providing replacement females for static terminals. Here, a rotation system produces replacement females both to keep itself going and for use in a separate terminal. In most instances, middle-aged females (4 to 6 years old) are moved out of the rotation to the terminal, because they are less prone to calving problems if terminal sires are large in body size. For a rotation terminal, only two breeding groups are needed—one for the sire rotation and one for the terminal cross.

Heterosis is relatively high in these rotation terminals, because all progeny and breeding females are crossbred. However, a high percentage of the rotation heifer progeny must be retained for replacements, so there is little opportunity for selection of females. Approximately 65 to 75 percent of sale calves are from the terminal, with most of the rest being male calves from the rotation.

Composites

A composite is formed from two or more established breeds, usually in exact percentages that can vary depending on the goals. There is specific attention given to retaining heterosis as generations progress. The primary motivation for creating composites is to create desirable breed combinations while producing some heterosis without continual crossbreeding.

Composites as discussed above are not breeds in the usual sense of the word. There are numerous breeds that have been created by combining existing breeds. Formula breeds contain specific percentages of the constituent breeds. Pool breeds do not have specified percentages. These combination breeds also retain some heterosis, but that is not usually a primary motivation in their creation or propagation.

For a more complete discussion of this subject, see another publication in this series, E-180, "Texas Adapted Genetic Strategies for Beef Cattle—VI: Creating Breeds and Composites."

Breeding Systems and Breeding Groups

The choice of breeding systems depends partly on the number of separate breeding groups that can be maintained. The development, breeding, and calving of heifers is conducted most efficiently in a management group separate from older females using easy-calving sires.

One breeding group

One-breeding-group herds, ranging from those requiring only one bull to large, multiple- sire herds, have several choices of breeding systems. Straightbreeding is an option, which could be done with either a traditional or combination breed. A static terminal cross could be run, with F_1 females being purchased. A sire rotation could be implemented, using breeds that are similar in functional characteristics. A fourth option for one breeding group is the use of a composite.

Two breeding groups

Two groups offer other choices including:

- True two-breed rotation
- Straightbreeding in one group to produce females for use in another group, particularly to create F_1 replacement females
- Straightbreeding in one group to produce females for a two-breed static terminal cross in another group

- Purchasing straightbred females for creation of an F_1 in one group to be used in a three-breed static terminal cross in another group
- Sire rotation in one group, producing replacement females for a terminal cross in another group.

Three breeding groups

There are three options that require three breeding groups. One is a true three-breed rotation. Another is a true two-breed rotation generating replacement females for a terminal cross. The third is to carry out all three matings for a complete three-breed static terminal cross (production of straightbred females, creation of F_1 females, and the terminal cross).

Multiple breeding groups are more complex to manage, and for each breeding group there is a different breed composition in market animals. This can reduce marketing flexibility. Also, some breed combinations may be less valuable than others. Consider these factors before implementing systems requiring multiple breeding groups.

Efficiencies of Breeding Systems

To compare breeding systems at the cow-calf level, a simple measure of production efficiency is pounds of calf weaned per cow exposed to breeding, which combines reproductive efficiency and calf weight. Table 1 compares several breeding systems on this basis. Values shown are percentage increases above continuous straightbreeding. These increases are due to average levels of heterosis and any progeny weight increase from large terminal sires.

As shown in the table, simple continuous systems requiring a single breeding group (sire rotations and composites) can increase efficiency by about 10 percent to 20 percent. Most of the more complicated plans (true rotations, terminals, and combinations) increase efficiency about 15 percent to more than 25 percent. These estimates are for systems using British and Continental breeds in temperate environments. In harsh tropical or subtropical environments, including tropical-adapted breed types can produce even greater increases. These are significant advantages over straightbreeding.

In choosing a breeding system, possible effects on the major profit factors should be considered, including:

- Number of animals to sell
- Pounds per animal
- Price per pound
- Total cost of production.

The measure of efficiency used in Table 1, pounds of calf per cow exposed, lacks any consideration of animal numbers. Larger cows may wean more pounds per cow. But fewer large cows can be run on the same piece of land, so the number of sale calves is reduced.

Pounds weaned per cow does not take into account price per pound. Some breed combinations typically receive price discounts, some severe. Also, heavier calves bring less per pound. Finally, pounds of calf per cow exposed does not consider cost of production. If high levels of reproduction and calf weight increase costs (particularly nutrition costs), the advantage of crossbreeding may be reduced. Research indicates that when all costs are included, the total economic advantage from crossbreeding may drop approximately two-thirds to three-fourths of the levels shown in Table 1, still an important advantage.

It is a major challenge for beef cattle producers to select breeding systems and breeds compatible with climate, forage conditions, general management practices, and market demands. For a discussion of genetic types and breeds of cattle, see another publication in this series, E-190, "Texas Adapted Genetic Strategies for Beef Cattle—V: Type and Breed Characteristics and Uses."

When selecting a breeding system, give careful thought to the entire process. Do not embark on the first stage of a system without planning for subsequent stages. A system that works well for one producer might be completely unsuitable for another.

Table 1. Breeding system production efficiencies.

System	Advantage[1]
2-breed true rotation	16
3-breed true rotation	20
2-breed sire rotation	12
3-breed sire rotation	16
2-breed composite[2]	12
4-breed composite[2]	18
2-breed static terminal (complete)	9
3-breed static terminal (complete)	20
3-breed static terminal (buy F_1 females)	28
3-breed sire rotation or composite[2] + terminal cross	24

[1]Average percent increase over straightbreeding in pounds of calf weaned per cow exposed, using only *Bos taurus* breeds (British and Continental European). Crossing *Bos taurus* and *Bos indicus* (Zebu) can increase these values by 50 to 100 percent, depending on the environment.

[2]Substituting a combination breed for a composite reduces values slightly to moderately, depending on heterosis retained.

References

Gregory, K.E. and L.V. Cundiff, 1980. "Crossbreeding in beef cattle: evaluation of systems." *J. Animal Sci.* 51:1224.

Long, C.R. 1980. "Crossbreeding for beef production; experimental results. *J. Animal Sci.* 51:1197.

Franke, D.E. 1980. "Breed and heterosis effects of American Zebu Cattle." *J. Animal Sci.* 50:1206.

Koger, M. 1980. "Effective Crossbreeding Systems Utilizing Zebu Cattle." *J. Animal Sci.* 50: 1215.

Gregory, K.E., L.V. Cundiff and R.M. Koch. 1992. "Composite breeds to use heterosis and breed differences to improve efficiency of beef production." U.S.D.A. - ARS, U.S. Meat Animal Research Center Tech. Rpt.

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