Applying Principles of Crossbreeding to Maximize Hybrid Vigor

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One of the most powerful tools available to cattle producers to improve productivity and efficiency in a herd is the use of crossbreeding. Effective use of a crossbreeding system allows producers to take advantage of heterosis (hybrid vigor), breed complementarity, and biological breed type differences to match cattle to specific production resources.

Failure to adequately implement a proper crossbreeding program can potentially decrease the level of hybrid vigor observed. Improper implementation with no regard to breed complementarity or breed background of the breeding herd can lead to a herd which lacks both uniformity and the ability to produce under a given set of available resources.

Heterosis

Heterosis is the superior performance of a crossbred or hybrid offspring over the average of the parental breeds. It can have a marked effect on profitability and productivity in a cattle operation. Heterosis, or hybrid vigor, is greatest when crossing two parent animals of completely different breed backgrounds. Hybrid vigor can be exhibited through a variety of traits such as increased survivability and growth of crossbred calves or higher reproduction rates of crossbred cows.

The major factor that leads a producer to enter a crossbreeding system should be to optimize cattle performance and efficiency in a specific production environment. The amount of heterosis that is maintained in a herd depends on the type of crossbreeding system the producer implements and the number of breeds being incorporated into the crossbreeding system.

Breed Differences and Breed Complementarity

Generally speaking, the amount of variability between breeds for most traits is comparable to the amount of variability one would expect to find between individuals within a breed. All breeds manifest superiority in some of the economically important traits, but no breed can boast excellence in all traits.

A crossbreeding program should be designed to capitalize on those traits that each of the parent breeds bring to the mix. This is known as breed complementarity, or a mating that will generate a hybrid offspring that is overall superior in a specific production environment than the parents. Breed complementarity helps match the genetic potential for all the economically important traits such as growth rate and carcass composition with climate, feed resources, fertility, disease resistance and market preferences. Simply put, breed complementarity means that the strengths of one breed can complement or mask the weaknesses of another breed in the hybrid offspring.

In poorly conceived crossbreeding programs, breed complementarity could have negative effects on productivity. For example, if a large, paternal sire breed with large milk potential were bred to small framed, heifers on a limited forage system, this could result in dystocia and replacement animals being incorporated that were not compatible with the producer's resources.

Cattle breeds can be separated into different biological types, with each type exhibiting differing levels of production for various production characteristics. The most common biological breed types utilized in the United States are the Bos Taurus (Old English, Continental) and Bos Indicus (Brahman) breed types. Table 1 lists some breeds grouped by biological type.

Table 1. Cattle breeds grouped by biological type.[1]

Breed	Milk production	Growth rate and mature size	Percentage retail product	Age at puberty
Jersey	*****	*	*	*
Hereford	**	**	*	***
Angus	***	**	*	**
Brahman	***	***	***	*****
Tarentaise	****	***	****	**
Simmental	****	*****	*****	**
Gelbvieh	****	****	****	*
Maine Anjou	**	*****	****	**
Limousin	*	***	*****	****
Charolais	**	*****	*****	****
Chianina	**	*****	*****	****

[1]Increasing number of * indicates greater values for a particular trait. For example, ***** = greatest milk production or oldest age at puberty and ** = below average percentage of retail product. From Gosey.

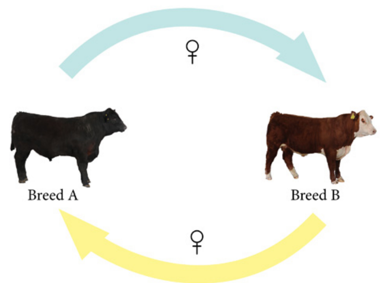
One excellent crossbreeding example that maximizes breed complementarity of different biological types is very common in the Southeastern United States. A Hereford or Angus bull is bred to Brahman cows to produce a medium framed, moderate milking F1 female that will be breed back to a *Bos Taurus* type bull. These F1 females are more heat and parasite resistant than their *Bos Taurus* sire breed but are more early maturing sexually and will produce calves with better carcass quality than their *Bos Indicus* dam breed.

Crossbreeding Systems

Crossbreeding systems use heterosis, biological type breed differences, and breed complementarity with varying degrees of success. The main goal of any crossbreeding system is not only to maximize hybrid vigor but to retain high levels of hybrid vigor for multiple generations. Table 2 illustrates how multiple breed crossbreeding systems maximize retained hybrid vigor (RHV). Table 3 demonstrates how RHV works in a three-breed rotational crossbreeding system using Charolais as the base herd.

Rotational Crossbreeding

Rotational crossbreeding systems are the most common and easiest to implement systems. These include the two-breed rotation, three-breed rotation and two-breed rotation with mature cows being bred to a terminal sire breed. In the two-breed rotation, cows sired by breed A are bred to bulls from breed B, and cows sired by breed B are bred to bulls from breed A (Fig. 1). The three-breed rotation simply adds a third breed (breed C) into the rotation (Fig. 2). The two- and three-breed systems do require record keeping and additional breeding pastures to ensure the cows are bred by the correct bull breed.



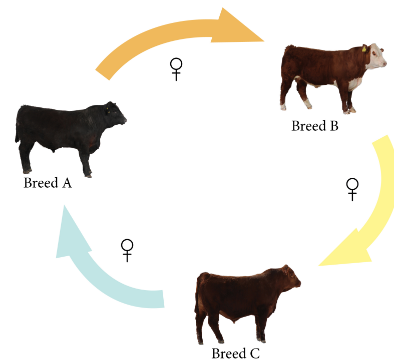


Fig. 1. Two-breed rotation.

Fig. 2. Three-breed rotation.

Table 2. Expected levels of heterosis, use of breed effect, and complementarity for various crossbreeding systems.

Mating scheme	% of maximum heterosis[1]	Breed effects[2]	Comple-mentarity[2]	Estimated increase in calf wt. weaned per cow exposed
Terminal sire x F_1 females	100	**	****	23 to 28
Two-breed rotation	67	**	0	16
Three-breed rotation	86	**	0	20
Two-breed rotation with terminal sire	90	**	***	21
Two-breed composite	50	***	**	12
Three-breed composite	63	***	**	15
Four-breed composite	75	***	**	18

[1]Relative to F_1 @ 100%

[2]Increasing number of * indicates greater values for a particular trait. For example, **** = greatest breed effects and complementarity and ** = low breed effect and complementarity.

Table 3. Levels of Retained Hybrid Vigor in a 3 Breed Rotational Crossbreeding System with a Charolais based female herd in Generation 1

Generation/Charolais based female herd	Breed of Sire	Breed Proportion Angus	Breed Proportion Hereford	Breed Proportion Charolais	% RHV
Charolais				100	0
1	Angus	50		50	100
2	Hereford	25	50	25	100
3	Charolais	12.5	25	63	75
4	Angus	56	13	31	88
5	Hereford	28	56	16	88
6	Charolais	14	28	58	84
7	Angus	57	14	29	86
8	Hereford	29	57	17	86
9	Charolias	14	29	57	86
10	Angus	57	14	29	

Another rotational cross that adds a slight variation accompanied by increased performance is the two-breed rotation crossed to a terminal sire breed (Fig.3). In this system, first-calf heifers and second-calf cows that meet the producers' selection criteria are retained in the two-breed rotation while all mature cows are bred to sires of a terminal breed. All offspring from the mature cows are marketed and none are retained in the breeding herd. This system retains as high a percentage of heterosis as any rotational cross while taking greater advantage of complimentarity.

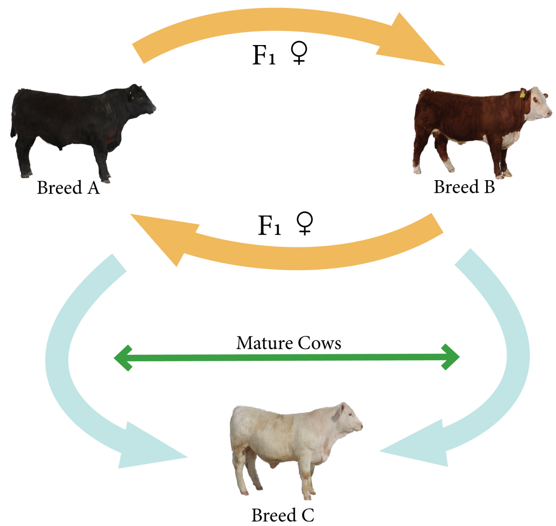


Fig. 3. Two-breed rotation with mature cows bred to a terminal bull.

Rotational-in-Time Crossbreeding Systems

A rotation-in-time crossbreeding system incorporates a new breed bull into the system every one or two years. For example, in year 1 an Angus bull would be mated to the herd, year 2 a Hereford bull, year 3 a Shorthorn bull, and year 4 a Simmental bull utilized. In this system bulls are introduced in yearly sequences in order maintain high levels of RHV and to minimize one specific breed becoming dominant in the herd. Although, this crossbreeding strategy is extremely effective at high levels of hybrid vigor, effective use of bulls may become an issue. With bulls being introduced in yearly sequences, a producer must obtain new breed bull types frequently and may be maintaining bulls of specific breeds that may not be in the breeding sequence for that year. Thus, the cost to purchase or maintain bulls that are not being utilized in the system can become costly if many breeds are incorporated into the rotation in time crossbreeding system.

Spatial Crossbreeding Systems

A spatial crossbreeding strategy is very similar to a rotation-in-time strategy except all breed bulls are utilized at the same time but are separated by pasture. In this system where three different breed bulls are utilized, the initial cow herd would be separated and put into bull pastures based off of which bull breed they share the least amount of breed background with. Each year replacement females that are to be kept for breeding will move out of the pasture in which their mothers were bred and will be placed with a bull in which they share the lease amount of breed background. While this system also maintains a high level of RHV, and utilizes bulls simultaneously throughout the breeding season, it is not without its disadvantages. The major disadvantage in this type of system is that a producer must have the land/pasture resources, and labor to separate and maintain multiple breeding herds throughout the breeding season.

Composite Populations

Composite breeds are designed to maintain high levels of RHV without further crossbreeding. Composite breeds, or American breeds as they are commonly referred to, typically have a defined proportion of two or more breeds in their background (Beefmaster, Santa Gertrudis etc). Just as with traditional crossbreeding systems the more breeds in the background, the higher level of RHV that will be observed. An example of developing a four-breed composite is seen in Fig. 4. The development phase of this crossing scheme is quite complex. However, after development the herd can be managed as a purebred herd.

Composite populations can maintain a relatively high amount of heterosis, providing there is an adequate population size to select replacements and new sires to avoid inbreeding.

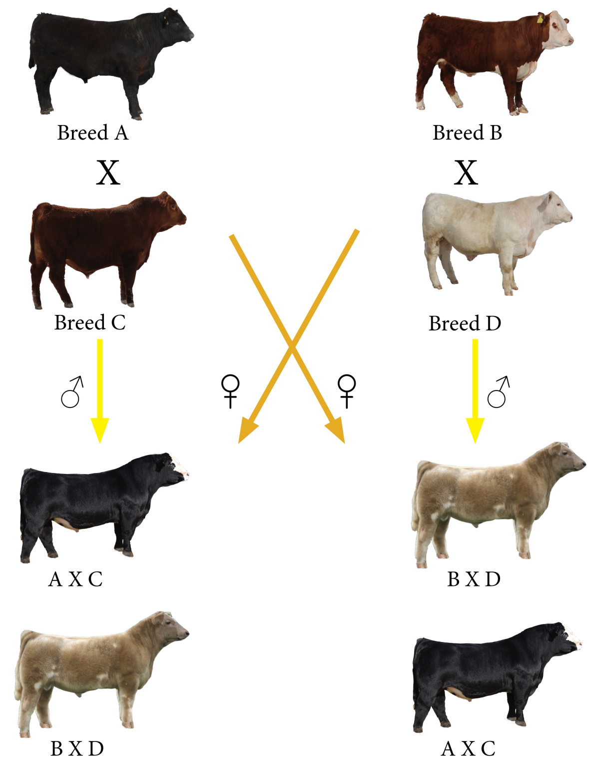


Fig. 4. Four-breed composite population development 1/4A, 1/4B, 1/4C, 1/4D.

Additionally, you will note that composite populations also make effective use of additive breed effects and complementarity in addition to heterosis to achieve increased productivity. Although these populations have a high level of RHV without further crossbreeding there are some disadvantages to composite breeds. The first is that if the composite is not widely utilized replacements and bulls from outside the producers herd may be difficult to locate, thus leading to inbreeding. The second major disadvantage has to do with the defined breed proportions that make up composite breeds. If the breeder decides they would like to regenerate a new line of the composite it will take many generations (depending on proportions and number of breeds) to generate the composite with the specific breed proportions of its ancestors.

Summary

Crossbreeding can be a powerful tool to improve the productivity and profitability of a beef cattle operation when it is used correctly. Conversely, it can reduce profitability if it is not contemplated fully before implementation.

Regardless of what type of crossbreeding system is decided upon, the producer must plan ahead for several generations, and not just for a few years. Initial decisions made at the outset of a program will impact the operation for many years to come.

No single crossbreeding system should be expected to fit every commercial cattle operation. When embarking on a crossbreeding program each of the following facets must be either resolved, or at least thoroughly considered for the program to be implemented successfully:

- Number of breeding pastures needed.

- How replacement heifers will be obtained or selected.
- Optimum herd size.
- Biological type and source of breeds to be used.
- Source of bulls.
- Feed resources required.
- Availability of labor.
- Potential use and feasibility of artificial insemination ?(This would need to be explained further as AI in crossbreeding strategies is a highly debatable topic in terms of cost effectiveness (AI program, clean up bulls still needed and hybrid vigor level is not going to be measurably different between live cover and AI calves.

Perhaps the most important question that must be answered after careful consideration of the above is whether the new system will fit the resources available to the operator. If all of these can be resolved, the producer can proceed to move forward with confidence toward optimal production and profitability.

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