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Crossbreeding Beef Cattle

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The economic climate of today's beef business is challenging. Commercial cow-calf producers are faced with optimizing a number of economically important traits, while simultaneously reducing costs of production in order to remain competitive. Traits such as reproduction, growth, maternal ability, and end product merit all influence productivity and profitability of the beef enterprise. Implementation of technologies and systems that both reduce costs and enhance productivity is essential. One of the oldest and most fundamental principles that has a positive influence on accomplishing these goals is crossbreeding.

Why Crossbreed?

Crossbreeding beef cattle offers two primary advantages relative to the use of only one breed: 1) crossbred animals exhibit *heterosis* (hybrid vigor), and 2) crossbred animals combine the strengths of the various breeds used to form the cross. The goal of a well-designed, systematic crossbreeding program is to simultaneously optimize these advantages of heterosis and breed complementarity.

Heterosis or hybrid vigor refers to the superiority in performance of the crossbred animal compared to the average of the straightbred parents. Heterosis may be calculated using the formula:

$$\% \text{ Heterosis} = [(\text{crossbred average} - \text{straightbred average}) \div \text{straightbred average}] \times 100$$

For example, if the average weaning weight of the straightbred calves was 470 pounds for Breed A and 530 pounds for Breed B, the average of the straightbred parents would be 500 pounds. If Breed A and Breed B were crossed and the resulting calves had an average weaning weight of 520 pounds, heterosis would be calculated as:

$$[(520 - 500) \div 500] \times 100 = 4\ \%$$

This 4% increase, or 20 pounds in this example, is defined as heterosis or hybrid vigor.

The amount of heterosis expressed for a given trait is inversely related to the heritability of the trait. Heritability is the proportion of the measurable difference observed between animals for a given trait that is due to genetics (and can be passed to the next generation). Reproductive traits are generally low in heritability (less than 10%), and therefore respond very slowly to selection pressure since a very small percentage of the differences observed among animals is due to genetic differences (a large proportion is due to environmental factors). The amount of heterosis is largest for traits that have low heritabilities. This has significance for commercial breeding systems, as crossbreeding can be used to enhance reproductive efficiency. To date, the ability to select for reproduction is limited (ie. there are no EPDs for reproduction). Traits that are moderate in their heritabilities (20 to 30%) such as growth rate are also moderate in the degree of heterosis expressed (around 5%). Highly heritable traits (30 to 50%) such as carcass traits exhibit the lowest levels of heterosis.

Improvements in production from heterosis may be captured by having both a crossbred calf and a crossbred cow. The following two tables summarize the effects of individual heterosis (crossbred calf) and maternal heterosis (crossbred cow). These tables include results from numerous crossbreeding studies conducted in the Southeast and Midwest involving several breeds. The advantage of the crossbred calf is two-fold: an increase in calf livability coupled with an increase in growth rate. Perhaps the most important advantage for crossbreeding is realized in the crossbred cow. Maternal heterosis results in improvements in cow fertility, calf livability, calf weaning weight, and cow longevity. Collectively, these improvements result in a significant advantage in pounds of calf weaned per cow exposed, and superior lifetime production for crossbred females.

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Individual Heterosis: Advantage of the Crossbred Calf[1]

Trait	Observed Improvement	% Heterosis
Calving rate, %	3.2	4.4
Survival to weaning, %	1.4	1.9
Birth weight, lb.	1.7	2.4
Weaning weight, lb.	16.3	3.9
ADG, lb./d	.08	2.6
Yearling weight, lb.	29.1	3.8

[1]Adapted from Cundiff and Gregory, 1999.

Maternal Heterosis: Advantage of the Crossbred Cow[1]

Trait	Observed Improvement	% Heterosis
Calving rate, %	3.5	3.7
Survival to weaning, %	.8	1.5
Birth weight, lb.	1.6	1.8
Weaning weight, lb.	18.0	3.9
Longevity, yr.	1.36	16.2
Cow Lifetime Production:		
No. Calves	.97	17.0
Cumulative Wean. Wt., lb.	600	25.3

[1]Adapted from Cundiff and Gregory, 1999.

The other important advantage to crossbreeding is the ability to take advantage of the strengths of two or more breeds to produce offspring that have optimum levels of performance in several traits. As an example, British breeds generally excel in marbling potential whereas Continental breeds typically are superior for red meat yield (cutability). Combining the breed types results in offspring that have desirable levels of both quality grade (marbling) and retail yield (yield grade). Similarly, milk production and growth rate may be most effectively optimized by crossing two or more breeds.

It is important to realize that the crossbred offspring will not excel both of the parent breeds for all traits. In the example given previously, straightbred calves of Breed B would have had heavier weaning weights (530 pounds) than the Breed A x Breed B crossbreds (520 pounds). However, Breed B females may be larger in mature size and have higher milk production potential resulting in increased nutitional requirements and higher production costs. Limited feed resources coupled with very high milk production may result in lower reproductive performance. Therefore, the cumulative effect of crossbreeding when several traits are considered is more important than the effect on any one particular trait. Effective crossbreeding programs must be designed to optimize performance, not necessarily maximize it.

Crossbreeding Systems

The success of a crossbreeding program will depend on its simplicity and ease of management. There are several factors and challenges that need to be considered when evaluating choice of crossbreeding system, including:

1) Number of cows in the herd
2) Number of available breeding pastures
3) Labor and management
4) Amount and quality of feed available
5) Production and marketing system
6) Availability of high-quality bulls of the various breeds

The design of any crossbreeding program should take advantage of both heterosis and breed complementarity. An ideal crossbreeding program should 1) optimize, but not necessarily maximize, heterosis in both the calf crop and particularly the cow herd, 2) utilize breeds and genetics that fit the feed resources, management, and marketing system of the operation, and 3) be easy to apply and manage.

Two-Breed Rotational Cross

The two-breed rotational cross or criss-cross is a relatively simple and popular form of crossbreeding. In this system, two breeds are mated and the resulting female offspring are kept as replacements and mated back to one of the breeds. In following generations, females are bred to the opposite breed of their sire. For example, if Angus and Gelbvieh were crossed to make 1/2 Angus x 1/2 Gelbvieh females who were then bred to Angus, the resulting calves would be 3/4 Angus x 1/4 Gelbvieh. These females would then be mated to Gelbvieh bulls. For their entire lives, females would be mated to the bull breed opposite their sire. This system would require a minimum of two breeding pastures (if only natural service is used), one for each breed of sire, and cows need to be identified by breed of sire. A critical component for this system is that the two breeds that are utilized must be reasonably compatible in biological type. Both breeds must be suitable as both sire and dam breeds. The two breeds utilized in this system should be similar in mature size, and individual bulls selected to avoid large differences in birth weight, milk production, and cow size/nutritional requirements from one generation to the next. An advantage to this system is the use of the crossbred cow, with pounds of calf weaned per cow exposed increased approximately 15% compared to the average of the breeds used in the cross. Over several generations, 67% of the maximum amount of heterosis is realized. Additionally, there are a large number of heifers from which replacements may be selected.

If three breeds are used in the system instead of two, pound of calf weaned per cow exposed is expected to increase by approximately 20% relative to the average of the three breeds used in the cross, and average heterosis over several generations attains 87% of maximum. However, three breeding pastures are necessary and significantly more management is required with the three breed vs. two breed rotational cross and a mimimum of 100 cows are needed. Additionally, finding three breeds that are compatible in biological type is more challenging. For these reasons, rotational crossbreeding systems beyond a two-breed rotation are not feasible for many producers.

Terminal Sire Systems

The addition of a third breed as a terminal sire to a two breed rotational cross system can further enhance the system. In this rota-terminal system, approximately 50% of the cowherd is mated to the terminal sire breed (a different breed than that used in the two-breed rotation) with the resulting offspring all marketed (no replacement females retained from the terminal sire matings). The other 50% of the cowherd operates as a two-breed rotation as outlined above. The two-breed rotation functions to produce all replacement females for the herd. Terminal sire breeds should be selected for calving ease, growth rate and carcass merit. Selection emphasis should concentrate on maternal performance, appropriate mature size, and longevity for the two breeds used to produce replacements. These selection criteria may simplify bull selection, and enhance the opportunity to specifically match genetics for their intended purpose. Older (> 4-5 years) and poorer producing cows are the best candidates for mating to the terminal sire. Younger cows should be genetically superior due to selection and should be used to produce the replacement females. The rota-terminal system has been shown to increase pounds of calf weaned per cow exposed by approximately 20%. Maximum heterosis is realized in the calves sired by the terminal breed, and advantages in maternal heterosis are realized as all females are crossbred. The rota-terminal system requires more management in that at least three breeding pastures are required (assuming all natural service). Additionally, less selection may be practiced on potential replacements, as a larger percentage of the eligible heifers must be retained to maintain herd size. The rota-terminal system is difficult to apply to herds with less than 100 cows.

Rotating Breeds of Sire

Rotating the breed of sire every three to four years may be a feasible crossbreeding option for producers who have small, single-sire herds. With this type of system, two sire breeds are used in rotation by replacing sire breeds every three to four years. A greater number of breeds may be utilized over an extended period of time. In single sire herds, bulls may need to be replaced more frequently, or AI used on heifers, to avoid father-daughter matings. This system is relatively simple yet maintains an acceptable level of heterosis. Pounds of calf weaned per cow exposed is increased 10-15%, dependent upon the number of sire breeds used.

A major challenge to making a crossbreeding program work is keeping the system sustainable without sacrificing optimum levels of heterosis and breed complementarity. The purchase of replacement females and the incorporation of an AI program are two means to assist with these challenges and have particular application for small herds.

Purchasing Replacement Females

The simplest, most manageable crossbreeding system utilizes purchased crossbred females mated to a third terminal sire breed. All calves are marketed in the system. Optimum heterosis can be realized in the cow as well as the calf crop. There are several advantages to this system, especially for small herds. First, management becomes simplified as heifers no longer need to be grown, developed, and bred. Bred females may be acquired, which have been confirmed pregnant to proven bulls for calving ease and other economically important traits. Secondly, bull selection is simplified since these terminal sires will be not be mated to heifers, and maternal traits are not of interest. Sire selection can focus specifically on acceptable calving ease and optimum growth and carcass merit. Additionally, only one breed of sire needs to be maintained. Remember that the health program, as well as the genetic package, are both acquired from the heifer supplier, so it is important that purchased heifers come from suppliers with a focused program of consistent genetic improvement. Of utmost interest is the economics of raising vs. purchasing replacement heifers. For many producers, purchasing females may be cost effective, especially when the contribution of the heifers to genetic progress of the herd is considered.

Use of Artificial Insemination

The use of artificial insemination may make the application of these described crossbreeding systems more feasible provided the expertise, labor, and facilities are available to make effective use of AI. The use of AI can significantly reduce the number of breeding pastures necessary for rotational cross or rota-terminal systems. Additionally, the use of AI may significantly reduce the number of bulls (and breeds) required for natural service. As an example, in a rota-terminal system the top 50% of the cows could be mated AI for the production of replacement females. Cows that did not conceive AI as well as the other 50% of the cows could be mated naturally to the terminal sire. This would reduce the number of breeding pastures required from three to one or two (depending on cow numbers). Additionally, in any system heifers could be bred AI to calving ease sires. Another major advantage to the use of AI is genetic improvement, as semen from superior bulls in any breed could be utilized.

Sire Selection for Crossbreeding Programs

As with any breeding system, sire selection is critical for genetic improvement. With crossbreeding systems, more than one breed of sire is typically used. As a result, the calf crop and female replacements are potentially sired by different breeds and individual bulls within those breeds. It is the differences between the breeds utilized, as well as differences in individual sires used, which contribute to variation in a set of cows or a calf crop. Therefore, for a crossbreeding system to be viable, sire selection (both within and between breeds) is critical for maintaining uniformity from one generation to the next, while at the same time taking advantages of the strengths of the various breeds used in the system.

Breed Selection

The most fundamental sire selection decision is the choice of breed. Choice of breeds to be used in the cross will be dependent on several factors, including the resources of the operation and the marketing program for the calf crop (specifically the targeted carcass merit endpoint). Considerable differences between breeds exist and may be effectively utilized by crossbreeding (see VCE Publication 400-803 , Beef Cattle Breeds and Biological Types). As mentioned previously, optimum performance rather then maximum performance is desired for virtually all economically important traits. For this reason, 1/2 to 3/4 British x 1/4 to 1/2 Continental females tend to optimize mature size, milk production, and adaptability for many Virginia producers. Similarly, a tremendous amount of growth potential can be added through breed selection. The breeds chosen and the percentage of each breed represented in the calf crop also have a pronounced impact on carcass characteristics. Coupling the general superiority of the British breeds for marbling potential with the red meat yield advantages of the Continental breeds results in offspring that have desirable levels of both quality grade (marbling) and retail yield (yield grade). The specific end product target will dictate the combination/percentage of breeds that are most likely to generate cattle with the desired carcass traits. Utilizing breed differences for carcass traits to match marketing grids will be important for producers as more retained ownership and value-based marketing is practiced.

Crossbreeding Sire Selection Using EPDs

Selection of bull within breed is equally important. EPDs are a very useful and important tool in accomplishing this task (see VCE Publication 400-804, Understanding Expected Progeny Differences). At the same time, breed strengths and weaknesses and the genetic merit of a breed as a whole for a particular trait also need to be considered when bulls are selected for use in a crossbreeding system. In other words, EPDs need to be considered on both a within and across-breed basis for effective bull selection in a crossbreeding program. Using the EPDs in this manner will assist the producer in minimizing large fluctuations in performance and production from one generation to the next when using more than one breed.

The following table can be used to compare the EPDs of bulls from two different breeds. To put the EPDs on a comparable basis, simply add or subtract the adjustment factor to the within-breed EPD of the bull. For example, consider a Simmental bull with a WW EPD of +35 and a Charolais bull with WW EPD of +20. To fairly compare the WW EPDs of these two bulls of different breeds, the EPDs must first be adjusted using the across-breed table. Using the table, the Simmental bull would have an across-breed WW EPD of +55.7 (35 + 20.7 = 55.7) and the Charolais bull an across-breed WW EPD of +57.7 (20 + 37.7 = 59.8). In this example, we would expect progeny of the Simmental bull and Charolais bull to be very similar on the average for weaning weight (across breeds EPDs of 55.7 vs. 57.7, for only a 2.0 pound difference), even though their within-breed EPDs were quite different. Across-breed EPDs may be calculated for the growth and maternal traits of any breed listed in the table.

2001 Adjustment Factors to Add to EPDs of Various Breeds to Estimate Across-Breed EPDs[1]

Breed	Birth wt.	Weaning wt.	Yearling wt.	Milk
Angus	0.0	0.0	0.0	0.0
Charolais	10.5	37.7	50.8	6.0
Gelbvieh	5.8	8.1	-19.9	13.1
Hereford	3.6	0.4	-8.8	-14.4
Limousin	5.9	22.1	16.2	-1.0
Red Angus	3.3	-4.0	-5.7	---
Salers	5.1	26.9	35.1	12.4
Shorthorn	7.4	28.0	39.1	13.1
Simmental	6.8	20.7	18.1	13.2

[1]Adapted from Van Vleck and Cundiff, 2001.

These across-breed adjustments may be used to compare bulls of different breeds that are being used in the crossbreeding program for similar purposes (i.e. milk production in Gelbvieh and Simmental, or growth in Simmental and Charolais). The adjustment factors may also be useful in managing uniformity when breeds are rotated in a crossbreeding system to avoid large fluctuations in traits such as birth weight and milk. For example, using these adjustments, it can be demonstrated that a Gelbvieh bull with a milk EPD of +7 will add similar milk genetics to an Angus bull with a milk EPD of +20. Both the bulls would be +20 on an across-breed basis. This demonstrates the differences between the breeds that exist, as a Gelbvieh bull that is +7 for milk EPD ranks in the lower 10% of the Gelbvieh breed while an Angus bull that is +20 for milk EPD ranks in the top 30% of the Angus breed. With this in mind, Gelbvieh bulls that will add a moderate amount of milk can be selected to complement an Angus cow base. Similar calculations can be made for birth weight and growth. The key is to recognize the basic genetic differences between breeds, and then select bulls within those breeds with optimum genetics while avoiding extremes.

Other Important Considerations

Another key factor for crossbreeding sire selection is the matching of frame score across the individual bulls selected. Frame score has a strong relationship with cow size. Therefore, minimizing differences in the frame scores of the bulls used to produce replacement females will assist in minimizing differences in mature size of the resulting cowherd. Mature size and milk production are important traits to manage when designing a cowherd that is uniformly adapted to the resources of the operation.

For many feeder cattle producers, coat color is an economically important trait. Today's genetics offer the opportunity to stabilize coat color and still maintain a crossbreeding program. Technological advances such as DNA genotyping have made it possible to more easily manage coat color in several breeds. Therefore, coat color does not need to be a limiting factor to maintain a crossbreeding program.

Summary

A well-designed, manageable crossbreeding system is an important aspect in making genetic progress in the various economically important traits that drive profitability in today's beef industry. To accomplish this task, bull selection must consider both within and across-breed differences to optimize genetic progress in these traits that influence reproductive efficiency, maternal performance, growth and feed efficiency, and end product merit.

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