Crossbreeding for Commercial Beef Production

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Improvement of the economic position of the farm or ranch is an ongoing process for many commercial cow-calf producers. Profitability may be enhanced by increasing the volume of production (i.e., the pounds of calves you market) and/or the value of products you sell (improving quality). The reduction of production costs, and thus breakeven prices, can also improve profitability. More and more producers are finding that a structured crossbreeding system helps them achieve the goals of increasing productivity and reducing production costs. Indeed, pricing differences, popularity, and perceptions of utility of some breeds and color pattern have motivated producers to stray away from sound crossbreeding systems. The primary objective of this chapter is to illustrate the economic importance of crossbreeding and diagram a number of crossbreeding systems.

Why Crossbreed?

The use of crossbreeding offers two distinct and important advantages over the use of a single breed. First, crossbred animals have heterosis, or hybrid vigor. Second, crossbred animals combine the strengths of the parent breeds. The term "breed complementarity" is often used to describe breed combinations that produce highly desirable animals for a broad range of traits.

What Is Heterosis?

Heterosis refers to the superiority of the crossbred animal relative to the average of its straightbred parents. Heterosis is typically reported in percentage improvement in the trait of interest. For example, bulls of breed A, which have an average weaning weight of 550 pounds, are mated to cows of breed B, which have an average weaning weight of 500 pounds. The average weaning weight of the straightbred parents is then (550 + 500)/2 = 525. The F_1 (first cross) calves that result have an average weaning weight of 546 pounds. The percentage heterosis is 4% (0.04) or (546 - 525)/525. Heterosis percentage is computed as the difference between the progeny average and the average of the straightbred parents divided by the average of the straightbred parents.

Heterosis results from the increase in the heterozygosity of a crossbred animal's genetic makeup. Heterozygosity refers to a state where an animal has two different forms of a gene. It is believed that heterosis is the result of gene dominance and the recovery from accumulated inbreeding depression of pure breeds. Heterosis is, therefore, dependent on an animal having two different copies of a gene. The level of heterozygosity an animal has depends on the random inheritance of copies of genes from its parents. In general, animals that are crosses of unrelated breeds, such as Angus and Brahman, exhibit higher levels of heterosis, due to more heterozygosity, than do crosses of more genetically similar breeds such as a cross of Angus and Hereford.

Generally, heterosis generates the largest improvement in lowly heritable traits (Table 1). Moderate improvements due to heterosis are seen in moderately heritable traits. Little or no heterosis is observed in highly heritable traits. Heritability is the proportion of the observable variation in a trait between animals that is due to the genetics that are passed between generations and the variation observed in the animal's phenotypes, which are the result of genetic and environmental effects. Traits such as reproduction and longevity have low heritability. These traits respond very slowly to selection since a large portion of the variation observed in them is due to environmental factors and non-additive genetic effects, and a small percentage is due to additive genetic differences. Heterosis generated through crossbreeding can significantly improve an animal's performance for lowly heritable traits. Crossbreeding has been shown to be an efficient method to improve reproductive efficiency and productivity in beef cattle.

Improvements in cow-calf production due to heterosis are attributable to having both a crossbred cow and a crossbred calf. Table 2 below details the individual (crossbred calf) heterosis, and Table 3 describes the maternal (crossbred cow) heterosis observed for various important production traits. These heterosis estimates are adapted from a report by Cundiff and Gregory (1999) and summarize crossbreeding experiments conducted in the southeastern and midwestern areas of the United States.

Why Is It So Important to Have Crossbred Cows?

The production of crossbred calves yields advantages in both heterosis and the blending of desirable traits from two or more breeds. However, the largest economic benefit of crossbreeding to commercial producers comes from having crossbred cows. Maternal heterosis improves both the environment a cow provides for her calf as well as improves the reproductive performance, longevity, and durability of the cow. The improvement of the maternal environment, or mothering ability, a cow provides for her calf is manifested in the improvements in calf survivability to weaning and increased weaning weight. Crossbred cows exhibit improvements in calving rate of nearly 4% and an increase in longevity of more that one year due to heterotic effects. Heterosis results in increases in lifetime productivity of approximately one calf and 600 pounds of calf weaning weight over the lifetime of the cow. Crossbreeding can have positive effects on a ranch's bottom line by not only increasing the quality and gross pay weight of calves produced but also by increasing the durability and productivity of the brood cow.

How Can I Harness the Power of Breed Complementarity?

Breed complementarity is the effect of combining breeds that have different strengths. When considering crossbreeding from the standpoint of producing replacement females, one could select breeds that have complementary maternal traits such that females are most ideally matched to their production environment. Matings to produce calves for market should focus on complementing the traits of the cows and fine-tuning calf performance (growth and carcass traits) to the marketplace.

An abundance of research describes the core competencies (biological type) of many of today's commonly used beef breeds. Traits are typically combined into groupings such as maternal/reproduction, growth, and carcass. When selecting animals for a crossbreeding system, their breed should be your first consideration. What breeds you select for inclusion in your mating program will depend on a number of factors including the current breed composition of your cow herd, your forage and production environment, your replacement female development system, and your calf marketing endpoint. All of these factors help determine the relative importance of traits for each production phase. A detailed discussion of breed and composite selection is contained in this manual.

If you implement a crossbreeding system, do not be fooled into the idea that you no longer need to select and purchase quality bulls or semen for your herd. Heterosis cannot overcome low-quality genetic inputs. The quality of progeny from a crossbreeding system is limited by the quality of the parent stock that produced them. Conversely, do not believe that selection of extremely high-quality bulls or semen or choosing the right breed will offset the advantages of an effective crossbreeding system. Crossbreeding and sire selection are complementary and should be used in tandem to build an optimum mating system in commercial herds (Bullock and Anderson, 2004).

What Are the Keys to Successful Crossbreeding Programs?

Many of the challenges that have been associated with crossbreeding systems in the past are the result of undisciplined implementation of the system. With that in mind, one should be cautious to select a mating system that matches the amount of labor and expertise available to appropriately implement the system. Crossbreeding systems range in complexity from very simple programs such as the use of hybrid genetics, which is as easy as straight breeding, to elaborate rotational crossbreeding systems with four or more breed inputs. The biggest keys to success are the thoughtful construction of a plan and then sticking to it. Be sure to set attainable goals. Discipline is essential.

Crossbreeding Systems

The practical crossbreeding systems implemented in a commercial herd vary considerably from herd to herd. A number of factors determine the practicality and effectiveness of crossbreeding systems for each operation. These factors include herd size, market target, existing breeds in the herd, the level of management expertise, labor availability, grazing system, handling facilities and the number of available breeding pastures. It should be noted that in some instances the number of breeding pastures required can be reduced through the use of artificial insemination.

Additional considerations include the operations decision to purchase replacement females or select and raise replacements from the herd. Purchasing healthy, well-developed replacement females of appropriate breed composition can be the simplest and quickest way for producers, especially small operators, to maximize maternal heterosis in the cowherd. Regardless of the crossbreeding system selected, a long-term plan and commitment to it are required to achieve the maximum benefit from crossbreeding. A variety of crossbreeding systems are described on the following pages. These systems are summarized in Table 4 by their productivity advantage measured in percentage of pounds of calf weaned per cow exposed. Additionally the table includes the expected amount of retained heterosis, the minimum number of breeding pastures required, whether purchased replacements are required, the minimum herd size required for the system to be effectively implemented, and the number of breeds involved.

Table 1. Summary of heritability and level of heterosis by trait type.[a]

Trait	Heritability	Level of Heterosis
Carcass/end product Skeletal measurements Mature weight	High	Low (0 to 5%)
Growth rate Birth weight Weaning weight Yearling weight Milk production	Medium	Medium (5 to 10%)
Maternal ability Reproduction Health Cow longevity Overall cow productivity	Low	High (10 to 30%)

[a] Adapted from Kress and MacNeil. 1999.

Table 2. Individual units and percentage of heterosis by trait.

Trait	Heterosis Units	Percentage (%)
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
Yearling weight, lb	29.1	3.8
Average daily gain, lb/d	0.08	2.6

Table 3. Maternal units and percentage of heterosis by trait.

Trait	Heterosis Units	Percentage (%)
Calving rate, %	3.5	3.7
Survival to weaning, %	0.8	1.5
Birth weight, lb	1.6	1.8
Weaning weight, lb	18.0	3.9
Longevity, years	1.36	16.2
Lifetime Productivity		
Number of calves	0.97	17.0
Cumulative weaning wt., lb	600	25.3

Table 4. Summary of crossbreeding systems by amount of advantage and other factors.[a]

Type of System		% of Cow Herd	% of Marketed Calves	Advantage (%)[b]	Retained Heterosis (%)[c]	Minimum No. of Breeding Pastures	Minimum Herd Size	No. of Breeds
2-breed rotation	A*B Rotation	100	100	16	67	2	50	2
3-breed rotation	A*B*C Rotation	100	100	20	86	3	75	3
2-breed rotational/Terminal sire	A*B Rotational	50	33			2		
	T x (A*B)	50	67			1		
	Overall	100	100	21	90	3	100	3
Terminal cross with straightbred females[d]	T x (A)	100	100	8.5	0	1	Any	2
Terminal cross with purchased F_1 females	T x (A*B)	100	100	24	100	1	Any	3
Rotate bull every 4 years	A*B Rotation	100	100	12	50	1	Any	2
	A*B*C Rotation	100	100	16	67	1	Any	3
Composite breeds	2-breed	100	100	12	50	1	Any	2
	3-breed	100	100	15	63	1	Any	3
	4-breed	100	100	17	75	1	Any	4
Rotating unrelated F_1 bulls	A*B x A*B	100	100	12	50	1	Any	2
	A*B x A*C	100	100	16	67	1	Any	3
	A*B x C*D	100	100	19	83	1	Any	4

[a] Adapted from Ritchie et al.
[b] Measured in percentage increase in lb of calf weaned per cow exposed.
[c] Relative to F_1 with 100% heterosis.
[d] Gregory and Cundiff, 1980.

Two-Breed Rotation

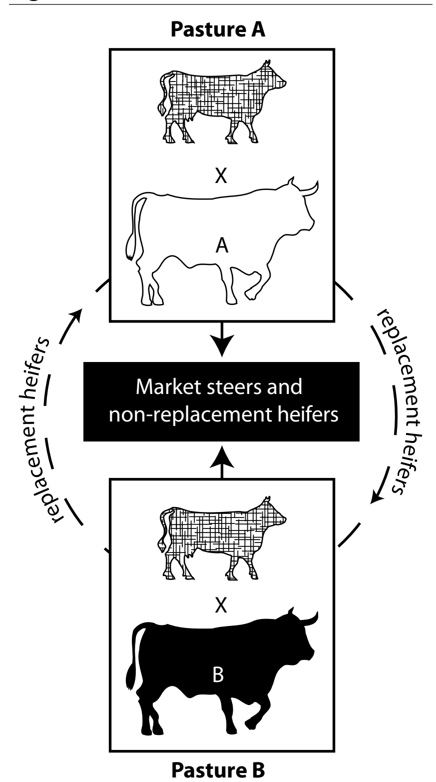
A two-breed rotation is a simple crossbreeding system requiring two breeds and two breeding pastures. The two-breed rotational crossbreeding system is initiated by breeding cows of breed A to bulls of breed B. The resulting progeny (A*B) chosen as replacement females would then be mated to bulls of breed A for the duration of their lifetime. Note the service sire is the opposite breed of the female's own sire. These progeny are then one-quarter breed A and three-quarters breed B. Since these animals were sired by breed B bulls, they are mated to breed A bulls. Each succeeding generation of replacement females is mated to the opposite breed of their sire. The two-breed rotational crossbreeding system is depicted in Figure 1. Initially only one breed of sire is required. Following the second year of mating, two breeds of sire are required.

After several generations, the amount of retained heterosis stabilizes at about 67% of the maximum heterosis, resulting in an expected 16% increase in the pounds of calf weaning weight per cow exposed above the average of the parent breeds (Ritchie et al., 1999). This system is sometimes called a crisscross.

Requirements. A minimum of two breeding pastures is required for a two-breed rotational system if natural service is utilized exclusively. Replacement females must be identified by breed of sire to ensure proper matings. A simple ear tagging system may be implemented to aid in identification. All calves sired by breed A bulls should be tagged with one color (e.g., red), and the calves sired by bulls of breed B should be tagged with a different color (e.g., blue). Then at mating time, all the cows with red tags (sire breed A) should be mated to breed B bulls, and vice-versa.

Considerations. The minimum herd size is approximately 50 cows with each half being serviced by one bull of each breed. Scaling of herd size should be done in approximately 50 cow units to make the best use of service sires, assuming one bull per 25 cows. Replacement females are mated to herd bulls in this system, so extra caution is merited in sire selection for calving ease to minimize calving difficulty. Be sure to purchase bulls or semen from sires with acceptable calving ease (preferably) or birth weight EPD for mating to heifers. Alternatively, a calving ease sire(s) could be purchased to breed exclusively to first calf heifers regardless of their breed type. The progeny produced from these matings that do not conform to the breed type of the herd should all be marketed.

Figure 1. Two-breed rotation.



Breeds used in rotational systems should be of similar biological type to avoid large swings in progeny phenotype due to changes in breed composition. The breeds included have similar genetic potential for calving ease, mature weight and frame size, and lactation potential to prevent excessive variation in nutrient and management requirements of the herd. Using breeds of similar biological type and color pattern will produce a more uniform calf crop, which is more desirable at marketing time. If animals of divergent type or color pattern are used, additional management inputs and sorting of progeny at marketing time to produce uniform groups may be required.

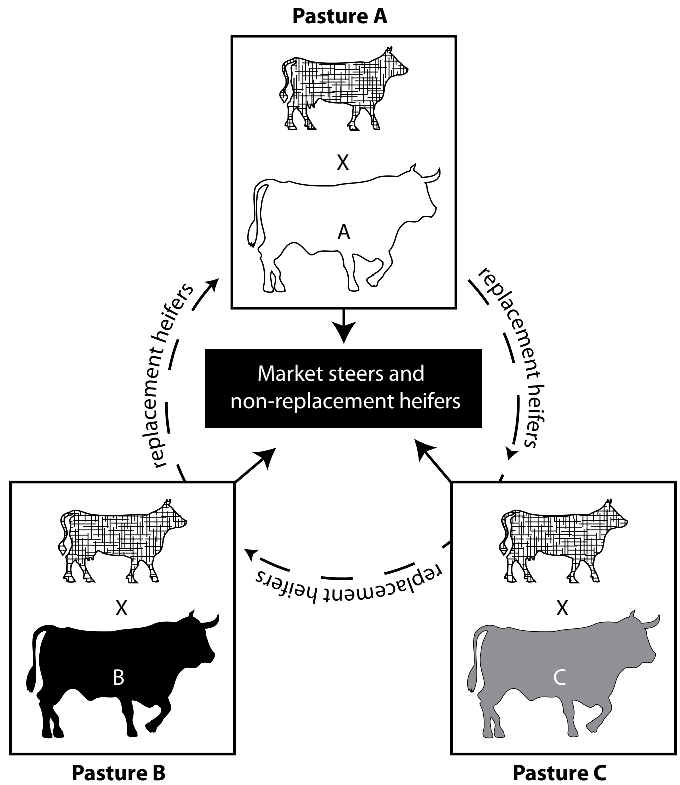
Three-Breed Rotation

A three-breed rotational system is very similar to a two-breed system in implementation with an additional breed added to the mix. This system is depicted in Figure 2. A three-breed rotational system achieves a higher level of retained heterosis than a two-breed rotational crossbreeding system does. After several generations, the amount of retained heterosis stabilizes at about 86% of the maximum heterosis, resulting in an expected 20% increase in the pounds of calf weaning weight per cow exposed above the average of the parent breeds (Ritchie et al., 1999). Like the two-breed system, distinct groups of cows are formed and mated to bulls of the breed that represents the smallest fraction of the cows breed makeup. A cow will only be mated to a single breed of bull for her lifetime.

Requirements. A minimum of three breeding pastures is required for a three-breed rotational system. Replacement females must be identified by breed of sire to ensure proper matings. A simple ear tagging system may be implemented to aid in identification. All calves sired by breed A bulls should be tagged with one color (e.g., red), the calves sired bulls of breed B should be tagged with a different color (e.g., blue), and the progeny of bulls of breed C tagged a third color (e.g., green). Then at mating time, all the cows with red tags (sired by breed A) should be mated to breed B bulls, cows with blue tags (sired by breed B) should be mated to breed C bulls, and, finally, all cows with green tags (sired by breed C) should be mated to breed A bulls.

Considerations. The minimum herd size is approximately 75 cows with each one-third being serviced by one bull of each breed. Scaling of herd size should be done in approximately 75 cow units to make the best use of service sires, assuming one bull per 25 cows. Replacement females are mated to herd bulls in this system, so extra caution is merited in sire selection for calving ease to minimize calving difficulty. Be sure to purchase bulls or semen from sires with acceptable calving ease (preferably) or birth weight EPD for mating to heifers. Alternatively, a calving ease sire(s) could be purchased to breed exclusively to first calf heifers regardless of their breed type. The progeny produced from these matings that do not conform to the breed type of the herd should all be marketed.

Figure 2. Three-breed rotation.



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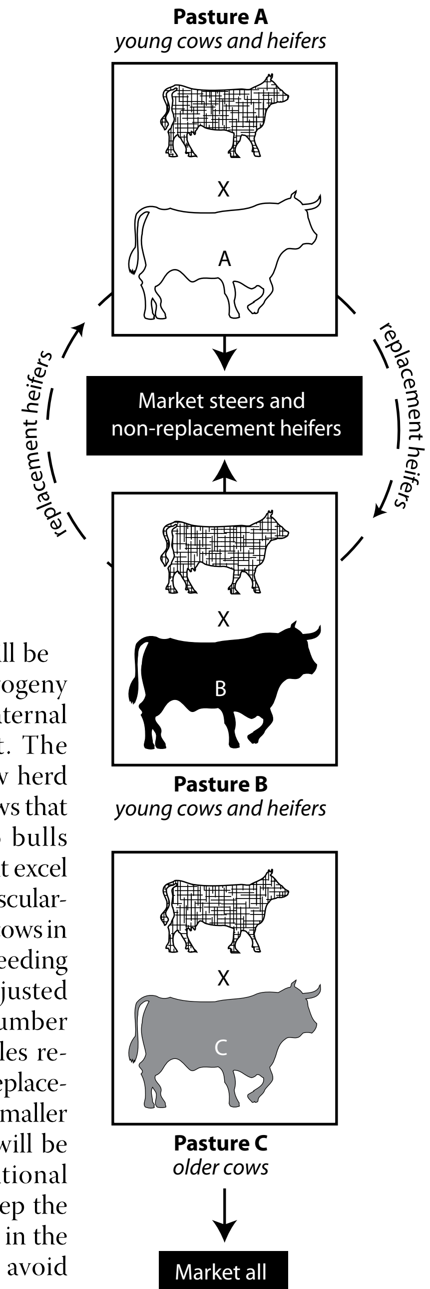
Two-Breed Rotational/Terminal Sire

The two-breed rotational with terminal sire system is sometimes called a rota-terminal system. It includes a two-breed rotational crossbreeding system of maternal breeds A and B. This portion of the herd is charged with producing replacement females for the entire herd, so maternal traits of the breeds included are very important. The remainder of the cow herd is bred to a terminal sire of a different breed as illustrated in Figure 3. In this system, approximately half of the cow-herd is committed to the rotational portion of the breeding system and half to the terminal sire portion. This system retains about 90% of the maximum heterosis and should increase weaning weight per cow exposed by approximately 21%.

Requirements. This system requires a minimum of three breeding pastures. Females in the rotational portion of the system must be identified by breed of sire. Minimum herd size is approximately 100 cows. Given the complexity of the breeding system and identification requirements, this system requires more management and labor to make it run effectively than some other systems do. The trade-off in systems that are easier to manage is that they typically yield lower levels of heterosis. If management expertise and labor are readily available, this system is one of the best for maximizing efficiency and the use of heterosis.

Figure 3. Two-breed rotational/terminal sire.



Considerations. The females in the rotational portion should consist of the youngest females, namely the 1-, 2-, and 3-year-olds. These females should be bred to bulls with both good calving ease and maternal traits. Calving ease and maternal traits are emphasized here because the cows being bred are the youngest animals where dystocia is expected to be highest. Additionally, replacement females for the entire herd will be selected from the progeny of these cows, so maternal traits are important. The remainder of the cow herd consists of mature cows that should be mated to bulls from a third breed that excel in growth rate and muscularity. The proportion of cows in each portion of the breeding system should be adjusted depending on the number of replacement females required. When fewer replacements are needed, a smaller portion of the herd will be included in the rotational system. Be sure to keep the very youngest groups in the rotational system to avoid dystocia problems. If ownership of calves will be retained through harvest, some consideration should be given to end product traits such as carcass weight, marbling, and leanness.

One drawback of the system is that there will be two different types of calves to market: one set from the maternally focused rotational system and one from the terminal sire system. Sorting and marketing can typically help offset this problem. The benefits of the rota-terminal system are usually worth the limitations.

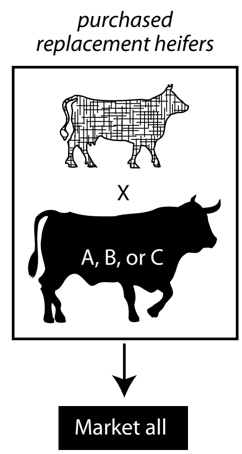
Two-Breed Terminal Sire

A two-breed terminal cross system uses straightbred cows of one breed and a sire(s) of another breed. No replacement females are kept, and therefore all must be purchased. Since all calves are marketed, it is a terminal sire system. Charolais or Limousin sires used on Angus cows would be a common example. Implementations of two-breed terminal sire systems are not desirable or recommended as they do not employ any benefits of maternal heterosis as the cows are all straightbred. Remember most of the benefits of heterosis arise from the enhancement of reproduction and longevity traits of crossbred cows.

Terminal Cross with Purchased F_1 Females

The terminal cross system utilizes crossbred cows and bulls of a third breed as shown in Figure 4. This system is an excellent choice as it produces maximum heterosis in both the calf and cow. As such, calves obtain the additional growth benefits of hybrid vigor, while heterosis in the cows improves their maternal ability. The terminal sire system is one of the simplest systems to implement and achieves the highest use of heterosis and breed complementarity. All calves marketed will have the same breed composition. A 24% increase in pounds of calf weaned per cow exposed is expected from this system when compared to the average of the parent breeds.

Figure 4. Terminal cross with purchased F_1 females.



Requirements. The terminal cross system works well for herds of any size if high-quality replacement females are readily available from other sources. Only one breeding pasture is required. No special identification of cows or groups is required.

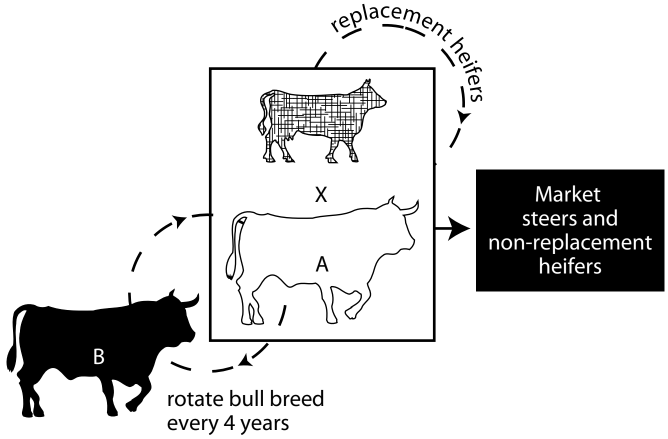
Considerations: Since replacement females are purchased, care should be given in their selection to ensure that they are fit to the production environment. Their adaptation to the production environment will be determined by their biological type, especially their mature size and lactation potential. Success of the system is dependent on being able to purchase a bull of a third breed that excels in growth and carcass traits. Virgin heifers should be mated to an easy calving sire to minimize dystocia problems. Disease issues are always a concern when introducing new animals to your herd. Be sure that replacement heifers are from a reputable, disease-free source and that appropriate bio-security measures are employed. Johne's, brucellosis, tuberculosis, and bovine viral diarrhea (BVD) are diseases you should be aware of when purchasing animals.

Another consideration and potential advantage of the terminal cross system is that replacement females do not need to be purchased each year depending on the age stratification of the original cows. In some cases, replacements may be added every two to five years, providing an opportunity to purchase heifers during periods of lower prices or more abundant supplies. Heifers could also be developed by a professional heifer development center or purchased bred to easy calving bulls.

Rotate Bull Every Four Years

This system requires the use of a single breed of sire for four years, then a rotation to a second breed for four years, then back to the original breed of sire for four years, and so on. This system is depicted in Figure 5. If a two-breed rotation is used, about 50% of the maximum heterosis will be retained, resulting in a 12% ex-

Figure 5. Rotate bull every four years.



pected improvement in weaning weight per cow exposed. If three breeds are utilized in the system, heterosis retention improves to 67% of maximum, and productivity advances 16%.

Requirements. The "rotate bulls every four years system" is particularly useful for small herds or herds with minimal management or labor inputs, as only one breeding pasture is required, and cows are not required to be identified by breed of sire. Replacement females are kept in this system.

Considerations. This system does not maximize heterosis retention, but it is very simple to implement and manage. The first breed of sire should be used for five calf crops if you start with straightbred cows to optimize retention of heterosis.

Composite Breeds

The use of composite populations in beef cattle has seen a surge in popularity recently. Aside from the advantages of heterosis retention and breed complementarity, composite population breeding systems are as easy to manage as straightbreds once the composite is formed. The simplicity of use has made composites popular among very large, extensively managed operations and small herds alike. When two-, three-, or four-breed composites are formed, they retain 50%, 67%, and 75% of maximum heterosis and improves productivity of the cowherd by 12%, 15%, and 17%, respectively. Thus, these systems typically offer a balance of convenience, breed complementarity, and heterosis retention.

Requirements. This system requires either a very large herd (500 to 1,000 cows) to form your own composite or a source of composite genetics. In closed populations, inbreeding must be avoided as it will decrease heterosis. To help minimize inbreeding in the closed herd where cows are randomly mated to sires, the foundation animals should represent 15 to 20 sire groups per breed, and 25 or more sires should be used to produce each subsequent generation (Ritchie et al., 1999). In small herds, inbreeding may be avoided through purchase of outside genetics that are unrelated to your herd. Due to the ease of use once the composite is established, composite systems can be applied to herds of any size or number of breeding pastures.

Considerations. Clearly, availability of outside seedstock is the limiting factor for most producers. However, with emerging popularity of structured, stabilized half blood systems (*inter se* mated F_1 animals) such as SimAngus, Balancer, and LimFlex, availability is much easier for these British x Continental crossbreds. Other composites have been formed and include MARC I, MARC II, MARC III, Rangemaker, Stabilizer, and others.

Rotating Unrelated F_1 Bulls

The use of F_1, or first cross, bulls resulting from the cross of animals from two breeds, is becoming more widespread. F_1 bulls provide a simple alternative to the formulation of composite breeds. Additionally, the F_1 systems may provide more opportunity to incorporate superior genetics as germplasm can be sampled from within each of the large populations of purebreds rather than a smaller composite population. The use of unrelated F_1 bulls, each containing the same two breeds, in a mating system with cows of the same breeds and fractions will result in a retention of 50% of maximum heterosis and an improvement in weaning weight per cow exposed of 12%. A system that uses F_1 bulls that have a breed in common with the cow herd (A*B x A*C) results in heterosis retention of 67% and an expected increase in productivity of 16%.

The use of F_1 bulls that do not have breeds in common with cows (A*B x C*D) retains 83% of maximum heterosis and achieves productivity gains of 19%. This last system is nearly equivalent to a three-breed rotational system in terms of heterosis retention and productivity improvement but is much easier to implement and manage. This system is similar to the two-breed rotation (Figure 1) or the rotating bull every four years (Figure 4) systems.

Requirements. The use of F_1 bulls requires a seedstock source, preferably locally, from which to purchase. The bulls will need to be of specific breed combinations to fit your program. These programs fit a wide range of herd sizes. The use of F_1 bulls on cows of similar genetic makeup is particularly useful for small herds as they can leverage the power of heterosis and breed complementarity using a system that is as simple as straightbreeding. Additionally, they can keep their own replacement females.

Considerations. The inclusion of a third or fourth breed in the system takes more expertise and management. To prevent wide swings in progeny phenotype, breeds B and C should be similar in biological type, while breeds A and D should be similar in biological type.

Crossbreeding Challenges

Although crossbreeding has many advantages, there are some challenges to be aware of during your planning and implementation, as outlined by Ritchie et al., 1999.

1. **More difficult in small herds.** Crossbreeding can be more difficult in small herds. Herd size over 50 cows provides the opportunity to implement a wider variety of systems. Small herds can still benefit through utilization of terminal sire, composite, or F_1 systems.
2. **Requires more breeding pastures and breeds of bulls.** Purchasing replacements and maximum use of AI can reduce the number of pastures and bulls. However, most operations using a crossbreeding system will expand the number of breeding pastures and breeds of bulls.
3. **Requires more record keeping and identification of cows.** Cow breed composition is a determining factor in sire breed selection in many systems.

4. **Matching biological types of cows and sire.** Breed complementarity and the use of breed differences are important advantages of crossbreeding. However, to best utilize them, care must be given in the selection of breeds and individuals that match cows to their production environment and sires to the marketplace. Divergent selection of biological type can result in wide swings in progeny phenotype in some rotational systems. These swings may require additional management input, feed resources, and labor to manage as cows or at marketing points.
5. **System continuity.** Replacement female selection and development is a challenge for many herds using crossbreeding systems. Selection of sires and breeds for appropriate traits (maternal or paternal traits) is dependent on the ultimate use of progeny. Keeping focus on the system and providing labor and management at appropriate times can be challenging. Discipline and commitment are required to keep the system running smoothly.

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