Breed and Composite Selection

Bob Weaber , University of Missouri

With more than 60 breeds of beef cattle present in the United States, the question of "which breed should I choose?" is a difficult question to answer. The top 10 breeds in fiscal year 2001 reported registrations accounting for 91% of the pedigreed beef cattle in the United States. These top 10 breeds and their crosses represent the majority of the genetics utilized in commercial beef production, providing a hint at the breeds that possess the most valuable combinations of traits as recognized by beef producers. The breed, composite, or combination of breeds employed in a breeding program can have a large impact on the profitability of a commercial beef operation and the value of animals it produces as they move through the beef complex. The breed or biological type of an animal influences economically important production traits including growth rate, mature size, reproductive efficiency, milk yield, and carcass merit.

Large differences exist today in the relative performance of various breeds for most economically important traits. These breed differences represent a valuable genetic resource for commercial producers to use in structured crossbreeding systems to achieve an optimal combination of traits matching the cowherd to their production environment and to use sire selection to produce market-targeted progeny. As such, the selection of the "right" breed(s) to use in a breeding program is an important decision for commercial beef producers. Determining this is highly dependent on a number of characteristics of a farm or ranch; therefore, not every operation should use the same breed or combination of breeds.

Breed and Composite Defined

A common definition of a breed is a genetic strain or type of domestic livestock that has consistent and inherited characteristics such as coat color or pattern, presence or absence of horns, or other qualitative criteria. However, one can also consider performance traits as common characteristics shared by individuals of a breed. In simple terms, these common characteristics are the performance traits that are often associated with a breed as its reputation has grown over time, and they represent the core traits for which a breed of livestock has been selected for over time. Breeds differ in the level of performance for various traits as a result of different selection goals of their breeders.

A composite is something that is made up of distinct components. In reference to beef cattle, the term composite generally means that the animal is composed of two or more breeds. Composite breeds are then groups of animals of similar breed composition. Composites can be thought of as new breeds and managed as such.

Beef Breed and Composite Characterization

A great deal of research has been conducted over the last 30 years at various federal and state experiment stations to characterize beef breeds in the United States. These studies have been undertaken to examine the genetic merits of various breeds in a wide range of production environments and management systems. During this time, researchers at the U.S. Meat Animal Research Center (MARC) have conducted the most comprehensive studies of sire breed genetic merit via their long-term Germplasm Evaluation (GPE) project. This project evaluated more than 30 sire breeds in a common environment and management system. The data summarized by the MARC scientists consisted of records on more than 20,000 animals born between 1978 and 1991, with a re-sampling of the most popular sire breeds in 1999-2000. The various sire breeds evaluated were mated to Angus, Hereford, and crossbred cows. Thus, the data reported were for crossbred progeny. During the study, Angus-Hereford crossbred calves were produced in the study as a control for each cycle of the GPE project.

One of the major outcomes of the GPE project was the characterization of sire breeds for a wide variety of economically important traits. Because all of the animals were in a common management system and production environment, the average differences observed in performance were due to genetic differences. Following the analysis of progeny data, the breeds can be divided into groups based on their biological type for four criteria: 1) growth rate and mature size, 2) lean to fat ratio, 3) age at puberty, and 4) milk production. The breeds evaluated at MARC are grouped by biological type in Table 1. British breeds such as Hereford, Angus, Red Angus, and Shorthorn, are moderate in growth and mature size, are relatively higher in carcass fat composition, reach puberty at relatively younger ages, and are moderate in milk production. Continental European breeds, with a heritage that includes milk production, including Simmental, Maine-Anjou, and Gelbvieh, tend to have high growth rates, larger mature sizes, moderate ages at puberty, and relatively high levels of milk production. Another group of Continental European breeds, with a heritage of meat and draft purposes, including Charolais, Chianina, and Limousin, tend to have high growth rate, large mature size, older ages at puberty, very lean carcasses, and low milk production.

Another way to compare the relative genetic merit of breeds for various performance traits is through conversion of their EPD to a common base. This can be accomplished using the across-breed EPD adjustments published each year in the proceedings of the Beef Improvement Federation's annual meeting. These adjustments are generated by researchers at MARC. Table 2 lists the across-breed adjustment factors that are added to the EPD of an animal of a specified breed to put that animal's EPD on an Angus base. Table 3 presents the average across-breed EPD of yearling bulls born in 2002-2003 from the most widely used breeds on a common genetic base (Angus) using the 2004 BIF across-breed EPD adjustments. Differences in across-breed EPD averages represent genetic differences for each trait. Table 3 provides a more contemporary look at the differences in breed genetic potential for various traits and accounting for genetic trends occurring in each breed due to selection. Due to selection pressure placed on growth and maternal traits over time, many breeds have made considerable gains in those traits. In some cases, the large gains in performance have resulted in subtle changes in the overall biological type of a breed. Producers are encouraged to seek

Table 1. Breed performance levels for seven traits in beef cattle.[a,b]

Breed Group	Growth Rate and Mature Size	Lean to Fat Ratio	Marbling (Intra-muscular Fat)	Tender-ness	Age at Puberty	Milk Production	Tropical Adaptation
Longhorn	X	XXX	XX	XX	XXX	XX	XX
Wagyu	X	XXX	XXXX	XXX	XX	XX	XX
Angus	XXXX	XX	XXXX	XXX	XX	XXX	X
Red Angus	XXXX	XX	XXXX	XXX	XX	XXX	X
Hereford	XXXX	XX	XXX	XXX	XXX	XX	X
Red Poll	XX	XX	XXX	XXX	XX	XXXX	X
Devon	XX	XX	XXX	XXX	XXX	XX	X
Shorthorn	XXXX	XX	XXXX	XXX	XX	XXX	X
Galloway	XX	XXX	XXX	XXX	XXX	XX	X
South Devon	XXX	XXX	XXXX	XXX	XX	XXX	X
Tarentaise	XXX	XXX	XX	XX	XX	XXX	X
Pinzgauer	XXXX	XXX	XXX	XXX	XX	XXX	X
Braunvieh	XXX	XXXX	XXX	XX	XX	XXXX	XX
Gelbvieh	XXXX	XXXX	X	XX	XX	XXXX	X
Simmental	XXXXX	XXXX	XX	XX	XXX	XXXX	X
Maine Anjou	XXXXX	XXXX	XX	XX	XXX	XXX	X
Salers	XXXX	XXXX	XX	XX	XXX	XXX	X
Piedmontese	XX	XXXXXX	X	XXX	XX	XX	XX
Belgian Blue	XXX	XXXXXX	X	XXX	XX	XX	X
Limousin	XXX	XXXXX	X	XX	XXXX	X	X
Charolais	XXXXX	XXXXX	XX	XX	XXXX	XX	X
Chianina	XXXXX	XXXXX	XX	XX	XXXX	X	XX
Tuli	XX	XXX	XXX	XX	XXX	XXX	XXX
Romosinuano	X	XXX	XX	XX	XXX	XXX	XXX
Brangus	XXXX	XXX	XXX	XX	XXX	XXX	XXX
Beefmaster	XXXX	XXX	XX	XX	XXX	XXX	XXX
Bonsmara	XXX	XXX	XX	XX	XXX	XXX	XXX
Brahman	XXXX	XXXX	XX	X	XXXXX	XXXX	XXXX
Nellore	XXXX	XXXX	XX	X	XXXXX	XXX	XXXX
Sahiwal	XX	XXXX	XX	X	XXXX	XXXX	XXXX
Boran	XXX	XXX	XX	X	XXXX	XXX	XXXX

a Cundiff, 2003.
b Increasing numbers of Xs indicate relatively higher value.

Table 2. 2004 Adjustment factors to add to EPD of 15 different breeds to estimate across-breed EPD.[a,b]

Breed	Birth Weight	Weaning Weight	Yearling Weight	Milk
Angus	0.0	0.0	0.0	0.0
Beefmaster	9.7	39.0	37.9	---
Brahman	13.0	34.8	-4.4	24.6
Brangus	5.7	20.0	20.4	---
Braunvieh	6.5	30.0	13.9	22.2
Charolais	10.5	38.4	53.4	2.6
Gelbvieh	5.4	7.1	-21.1	1.7
Hereford	3.4	-2.0	-13.7	-17.8
Limousin	4.5	1.8	-19.9	-15.9
Maine Anjou	6.7	17.6	5.5	7.6
Pinzgauer	7.7	28.3	25.5	6.1
Red Angus	3.6	-1.4	0.7	-7.8
South Devon	6.7	21.7	40.8	3.5
Salers	4.9	30.7	46.1	9.0
Shorthorn	7.8	31.4	44.5	12.1
Simmental	6.4	22.4	21.9	10.0
Tarentaise	3.6	30.1	13.4	17.8

a Van Vleck and Cundiff, 2004.
b Updates to across-breed EPD adjustments can be found at www.beefimprovement.org.

Table 3. Average across-breed EPD for non-parent animals born in 2002-2003 by breed.[a]

Breed	BW	WW	YW	MILK
Angus	2.6	35	65	17
Beefmaster	10.1	45	49	---
Brahman	15.1	51	22	32
Brangus	7.7	41	54	---
Braunvieh	7.6	37	21	22
Charolais	12.0	57	85	8
Gelbvieh	6.4	44	48	19
Hereford	7.2	33	46	-5
Limousin	6.9	36	44	2
Maine Anjou	9.2	34	37	11
Pinzgauer	7.6	29	26	5
Red Angus	4.1	27	49	6
Salers	7.8	34	60	12
Shorthorn	6.7	44	66	11
Simmental	9.7	65	102	18
South Devon	6.4	40	45	16

a Adjusted using the 2004 across-breed EPD adjustments listed in Table 2.

out the most current across-breed EPD adjustments as they are updated each year. The new across-breed EPD adjustments are available in each year's BIF conference proceedings at www.beefimprovement.org.

Use of Breeds and Composites for Genetic Improvement

Inclusion or exclusion of germplasm from a breed (or composite) is a valuable selection tool for making rapid directional changes in genetic merit for a wide range of traits. Changes in progeny phenotype that occur when breeds are substituted in a breeding program come from two genetic sources.

The first source of genetic impact from a substitution of a breed comes through changes in the *additive genetic effects* or breeding values that subsequent progeny inherit from their sire and dam. Additive genetic merit is the portion of total genetic merit that is transmissible from parent to offspring and on which traditional selection decisions are made. In other words, additive genetic effects are heritable. EPD are estimates of one-half of the additive genetic merit. The difference in average performance for a trait observed between two breeds is due primarily to differences in additive genetic merit.

The second source of genetic change is due to non-additive genetic effects. Non-additive effects include both dominance and epistatic effects. Dominance effects arise from the interactions of paired genes at each locus. Epistatic effects are the interaction of genes across loci. The sum of these interactions result in heterosis observed in crossbred animals. Since each parent contributes only one gene to an offspring and dominance effects depend on the interaction of a pair of genes, a parent cannot transmit dominance effects to its progeny within a breed. However, the selection of which breeds and how much of each breed to incorporate into progeny has a large impact on dominance (or heterosis) effects that affect phenotype. Epistatic effects arise from the interaction of genes at different loci. Independent segregation of chromosomes in the formation of gametes causes pairings of genes not to stay together from one generation to the next. Like dominance effects, epistatic effects are not impacted by mate selection but by the frequency of different alleles and their dominance effects across breeds.

Both additive and non-additive genetic effects can have a significant impact on a particular phenotype; therefore, it is important that both are considered during breed selection. Due to their different modes of inheritance, different tactics must be employed to capture the benefits of each.

Additive genetic merit may be selected for in two distinct ways. First, by the selection of individuals *within* a breed that have superior genetic merit for the trait under selection. Typically this is achieved through the use of EPD to identify selection candidates, although it can also be done through selection for specific alleles using DNA markers. The rate of improvement in phenotypes due to selection within breed is limited by the heritability of the trait. Heritability describes the proportion of phenotypic variation that is controlled by additive genetic variation. So, for traits with moderate to high heritability, considerable progress in progeny phenotype may be achieved through selection of superior animals within the breed as parent stock. The second approach to change additive genetic merit is through the selection of animals from a different breed(s) that excels in the trait under selection. *Across-breed selection* can provide rapid change in progeny phenotype given that large differences exist between breeds in a number of economically relevant traits. Selection of superior parent stock from a different breed that excels in a trait is often more effective than selection within a breed (Gregory et al., 1999) as the breed differences have a heritability of nearly 100%.

The use of breed differences across multiple traits *may be* achieved through the implementation of the concept of breed complementarity. Breeds are complementary to each other when they excel in different traits and their crossbred progeny have desirable levels of performance in a larger number of traits than either of the parent breeds alone. Making breed and mating selections that utilize breed complementarity provides an effective way to aggregate the core competencies of two or more breeds in the progeny. Moreover, use of breed complementarity can be a powerful strategy to genetically match cows to their production environment and progeny to the marketplace. For example, a crossbreeding system that mates Charolais bulls to Hereford-Angus crossbred cows utilizes breed complementarity. The Charolais bull contributes growth and carcass yield to progeny genetics, while the Hereford-Angus crossbred cows have many desirable maternal attributes and contribute genetics for carcass quality. 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 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 as described earlier and listed in Table 1. Traits are typically combined into groupings such as maternal/reproduction, growth, and carcass. When selecting animals for a crossbreeding system, breed should be the primary consideration. Breeds selected for inclusion in a mating program will be dependent on a number of factors including current cow herd breed composition, forage and production environment, replacement female development system, and calf marketing endpoint. All of these factors help determine the relative importance of traits for each production phase.

One of the challenges of breed selection is the interaction of the animal's genotype with its production environment. Table 4 describes common production environments by level of feed availability and environmental stress and lists optimal levels of a variety of performance traits (Bullock et al., 2002). Here, feed availability refers to the regular availability of grazed or harvested forage and its quantity and quality. Environmental stress includes parasites, disease, heat, and humidity. Ranges for mature cow size are low (800 to 1,000 lb), medium (1,000 to 1,200 lb), and high (1,200 to 1,400 lb) Clearly, breed choices should be influenced by the production environment in which they are expected to perform.

Crossing of breeds or lines is the primary method to exploit beneficial non-additive effects like heterosis. Heterosis refers to the superiority of the crossbred animal relative to the average of its straightbred parents, and heterosis results from an increase in 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 primarily 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.

Table 4. Matching genetic potential for different traits to production environments.[1]

Production Environment		Traits					
Feed Availability	Stress[2]	Milk Production	Mature Size	Ability to Store Energy[3]	Resistance to Stress[4]	Calving Ease	Lean Yield
High	Low	M to H[5]	M to H	L to M	M	M to H	H
	High	M	L to H	L to H	H	H	M to H
Medium	Low	M to H	M	M to H	M	M to H	M to H
	High	L to M	M	M to H	H	H	H
Low	Low	L to M	L to M	H	M	M to H	M
	High	L to M	L to M	H	H	H	L to M
Breed role in terminal crossbreeding systems							
Maternal		M to H	L to H	M to H	M to H	H	L to M
Paternal		L to M	H	L	M to H	M	H

[1] Adapted from Bullock et al., 2002.
[2] Heat, cold, parasites, disease, mud, altitude, etc.
[3] Ability to store fat and regulate energy requirements with changing (seasonal) availability of feed.
[4] Physiological tolerance to heat, cold, internal and external parasites, disease, mud, and other factors.
[5] L = Low; M = Medium; H = High.

Generally, heterosis generates the largest improvement in lowly heritable traits. Moderate improvements due to heterosis are seen in moderately heritable traits. Little or no heterosis is observed in highly heritable traits. 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 effects 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; thus, the importance of considering both additive and non-additive genetics when designing mating programs. Crossbreeding has been shown to be an efficient method to improve reproductive efficiency and preweaning productivity in beef cattle.

Improvements in cow-calf production due to heterosis are attributable to having both a crossbred cow and calf. Table 5 details the individual (crossbred calf) heterosis, and Table 6 describes the maternal (crossbred cow) heterosis observed for various important production traits (Cundiff and Gregory, 1999).

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 the crossbred cow. Maternal heterosis improves both the environment a cow provides for her calf as well as improves her longevity and durability. The improvement of the maternal environment a cow provides for her calf is manifested in 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.

The effects of maternal heterosis on the economic measures of cow-calf production have been shown to be very positive. The added value of maternal heterosis ranges from approximately $50/cow/year to nearly $100/cow/year depending on the amount of maternal heterosis retained in the cowherd (Ritchie, 1998). Maternal heterosis accounted for an increase in net profit per cow of nearly $75/cow/year (Davis et al., 1994) .Their results suggested that the benefits of maternal heterosis on profit were primarily the reduced cost per cow exposed. Crossbred cows had higher reproductive rates, longer productive lives, and required fewer replacements than straightbred cows in their study. All of these factors contribute to reduced cost per cow exposed. Further, they found increased outputs, including growth and milk yield, were offset by increased costs.

When it comes to crossing breeds with the goal of producing high levels of maternal or individual heterosis, not all breeds are equal. Heterosis depends on an animal having two different alleles or alternate forms of a gene at a locus. The likelihood of having different copies of genes at a locus is greater in breeds that are less related than when the breeds crossed are closely related. For instance, Angus and Hereford, both British breeds, are more similar than Angus and Simmental (a Continental European breed), which are more similar than Angus (a *Bos taurus* breed) and Brahman (a *Bos indicus* breed). Since heterosis offers considerable advantages to commercial producers in terms of reproduc-

Table 5. Individual units and percentage of heterosis by trait.

	Heterosis	
Trait	Units	%
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 6. Maternal units and percentage of heterosis by trait.

	Heterosis	
Trait	Units	%
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

tive efficiency, productivity, and economic returns, care should be given when selecting breeds for inclusion in a crossbreeding system. Just as breeds differ in the amount of heterosis generated when crossed, crossbreeding systems achieve differing levels of heterosis depending on the number of breeds and their fractions represented in each animal. A more complete discussion on crossbreeding and crossbreeding systems appears in a separate chapter in this manual.

When comparing two breeds for inclusion in a crossbreeding system that offer similar strengths, select the breed that offers the most heterosis when mated to animals of other breed(s) in your system. Table 7 provides estimates of the percentage increase in pairs of alleles at a locus that are different (heterozygosity) when various purebreds are crossed to form F_1 progeny. These estimates were developed using the input data and procedures suggested by Roughsedge and others (2001). It is easy to see that not all breeds offer the same increase in heterozygosity and, therefore, heterosis

Table 7. Increase in heterozygosity of F_1 animals when respective breeds are crossed.[a]

Breed	A	C	Ch	G	H	PH	L	MA	Sa	Sh	S	SD
Angus (A)	0.000	0.110	0.193	0.116	0.136	0.110	0.103	0.061	0.151	0.057	0.071	0.088
Charolais (C)	0.110	0.000	0.134	0.093	0.148	0.141	0.050	0.096	0.048	0.096	0.059	0.148
Chianina (Ch)	0.193	0.134	0.000	0.128	0.262	0.268	0.139	0.165	0.160	0.183	0.162	0.238
Gelbvieh (G)	0.116	0.093	0.128	0.000	0.183	0.189	0.110	0.151	0.114	0.137	0.063	0.149
Hereford (H)	0.136	0.148	0.262	0.183	0.000	0.011	0.172	0.163	0.195	0.110	0.151	0.183
Polled Hereford (PH)	0.110	0.141	0.268	0.189	0.011	0.000	0.166	0.139	0.198	0.089	0.148	0.172
Limousin (L)	0.103	0.050	0.139	0.000	0.172	0.166	0.000	0.081	0.057	0.094	0.071	0.112
Maine-Anjou (MA)	0.061	0.096	0.165	0.151	0.163	0.139	0.081	0.000	0.151	0.057	0.104	0.116
Salers (Sa)	0.151	0.048	0.160	0.114	0.195	0.198	0.057	0.151	0.000	0.175	0.069	0.211
Shorthorn (Sh)	0.057	0.096	0.183	0.137	0.110	0.089	0.094	0.057	0.175	0.000	0.115	0.093
Simmental (S)	0.071	0.059	0.162	0.063	0.151	0.148	0.071	0.104	0.069	0.115	0.000	0.139
South Devon (SD)	0.088	0.148	0.238	0.149	0.183	0.172	0.112	0.116	0.211	0.093	0.139	0.000

[a] Adapted from Roughsedge et al., 2001.

Table 8. Cow fertility expected heterosis (%) for F_1's (first cross).

Breed	A	C	Ch	G	H	PH	L	MA	Sa	Sh	S	SD
Angus (A)	0.00	7.32	12.87	7.76	9.05	7.32	6.87	4.05	10.04	3.77	4.77	5.85
Charolais (C)	7.32	0.00	8.97	6.21	9.89	9.43	3.35	6.43	3.21	6.43	3.91	9.89
Chianina (Ch)	12.87	8.97	0.00	8.51	17.50	17.85	9.27	10.97	10.66	12.23	10.82	15.90
Gelbvieh (G)	7.76	6.21	8.51	0.00	12.23	12.63	7.32	10.04	7.61	9.12	4.20	9.96
Hereford (H)	9.05	9.89	17.50	12.23	0.00	0.74	11.44	10.89	13.03	7.32	10.04	12.23
Polled Hereford (PH)	7.32	9.43	17.85	12.63	0.74	0.00	11.05	9.27	13.19	5.92	9.89	11.44
Limousin (L)	6.87	3.35	9.27	0.00	11.44	11.05	0.00	5.41	3.77	6.29	4.77	7.47
Maine-Anjou (MA)	4.05	6.43	10.97	10.04	10.89	9.27	5.41	0.00	10.04	3.77	6.95	7.76
Salers (Sa)	10.04	3.21	10.66	7.61	13.03	13.19	3.77	10.04	0.00	11.68	4.62	14.08
Shorthorn (Sh)	3.77	6.43	12.23	9.12	7.32	5.92	6.29	3.77	11.68	0.00	7.69	6.21
Simmental (S)	4.77	3.91	10.82	4.20	10.04	9.89	4.77	6.95	4.62	7.69	0.00	9.27
South Devon (SD)	5.85	9.89	15.90	9.96	12.23	11.44	7.47	7.76	14.08	6.21	9.27	0.00

Table 9. Birth weight expected heterosis (%) for F_1's.

Breed	A	C	Ch	G	H	PH	L	MA	Sa	Sh	S	SD
Angus (A)	0.00	2.64	4.65	2.81	3.27	2.64	2.48	1.47	3.63	1.36	1.72	2.11
Charolais (C)	2.64	0.00	3.24	2.24	3.57	3.41	1.21	2.32	1.16	2.32	1.41	3.57
Chianina (Ch)	4.65	3.24	0.00	3.08	6.32	6.45	3.35	3.96	3.85	4.42	3.91	5.75
Gelbvieh (G)	2.81	2.24	3.08	0.00	4.42	4.56	2.64	3.63	2.75	3.30	1.52	3.60
Hereford (H)	3.27	3.57	6.32	4.42	0.00	0.27	4.13	3.94	4.71	2.64	3.63	4.42
Polled Hereford (PH)	2.64	3.41	6.45	4.56	0.27	0.00	3.99	3.35	4.77	2.14	3.57	4.13
Limousin (L)	2.48	1.21	3.35	0.00	4.13	3.99	0.00	1.96	1.36	2.27	1.72	2.70
Maine-Anjou (MA)	1.47	2.32	3.96	3.63	3.94	3.35	1.96	0.00	3.63	1.36	2.51	2.81
Salers (Sa)	3.63	1.16	3.85	2.75	4.71	4.77	1.36	3.63	0.00	4.22	1.67	5.09
Shorthorn (Sh)	1.36	2.32	4.42	3.30	2.64	2.14	2.27	1.36	4.22	0.00	2.78	2.24
Simmental (S)	1.72	1.41	3.91	1.52	3.63	3.57	1.72	2.51	1.67	2.78	0.00	3.35
South Devon (SD)	2.11	3.57	5.75	3.60	4.42	4.13	2.70	2.81	5.09	2.24	3.35	0.00

Table 10. Survival to weaning expected heterosis (%) for F_1's.

Breed	A	C	Ch	G	H	PH	L	MA	Sa	Sh	S	SD
Angus (A)	0.00	1.90	3.34	2.01	2.35	1.90	1.78	1.05	2.60	0.98	1.24	1.52
Charolais (C)	1.90	0.00	2.33	1.61	2.56	2.44	0.87	1.67	0.83	1.67	1.02	2.56
Chianina (Ch)	3.34	2.33	0.00	2.21	4.54	4.63	2.41	2.85	2.77	3.17	2.81	4.12
Gelbvieh (G)	2.01	1.61	2.21	0.00	3.17	3.28	1.90	2.60	1.98	2.37	1.09	2.58
Hereford (H)	2.35	2.56	4.54	3.17	0.00	0.19	2.97	2.83	3.38	1.90	2.60	3.17
Polled Hereford (PH)	1.90	2.44	4.63	3.28	0.19	0.00	2.87	2.41	3.42	1.54	2.56	2.97
Limousin (L)	1.78	0.87	2.41	0.00	2.97	2.87	0.00	1.40	0.98	1.63	1.24	1.94
Maine-Anjou (MA)	1.05	1.67	2.85	2.60	2.83	2.41	1.40	0.00	2.60	0.98	1.80	2.01
Salers (Sa)	2.60	0.83	2.77	1.98	3.38	3.42	0.98	2.60	0.00	3.03	1.20	3.65
Shorthorn (Sh)	0.98	1.67	3.17	2.37	1.90	1.54	1.63	0.98	3.03	0.00	1.99	1.61
Simmental (S)	1.24	1.02	2.81	1.09	2.60	2.56	1.24	1.80	1.20	1.99	0.00	2.41
South Devon (SD)	1.52	2.56	4.12	2.58	3.17	2.97	1.94	2.01	3.65	1.61	2.41	0.00

Table 11. Weaning weight expected heterosis (%) for F_1's.

Breed	A	C	Ch	G	H	PH	L	MA	Sa	Sh	S	SD
Angus (A)	0.00	1.94	3.42	2.06	2.40	1.94	1.82	1.08	2.66	1.00	1.26	1.55
Charolais (C)	1.94	0.00	2.38	1.65	2.62	2.50	0.89	1.71	0.85	1.71	1.04	2.62
Chianina (Ch)	3.42	2.38	0.00	2.26	4.65	4.74	2.46	2.91	2.83	3.25	2.87	4.22
Gelbvieh (G)	2.06	1.65	2.26	0.00	3.25	3.35	1.94	2.66	2.02	2.42	1.11	2.64
Hereford (H)	2.40	2.62	4.65	3.25	0.00	0.20	3.04	2.89	3.46	1.94	2.66	3.25
Polled Hereford (PH)	1.94	2.50	4.74	3.35	0.20	0.00	2.93	2.46	3.50	1.57	2.62	3.04
Limousin (L)	1.82	0.89	2.46	0.00	3.04	2.93	0.00	1.44	1.00	1.67	1.26	1.98
Maine-Anjou (MA)	1.08	1.71	2.91	2.66	2.89	2.46	1.44	0.00	2.66	1.00	1.84	2.06
Salers (Sa)	2.66	0.85	2.83	2.02	3.46	3.50	1.00	2.66	0.00	3.10	1.23	3.74
Shorthorn (Sh)	1.00	1.71	3.25	2.42	1.94	1.57	1.67	1.00	3.10	0.00	2.04	1.65
Simmental (S)	1.26	1.04	2.87	1.11	2.66	2.62	1.26	1.84	1.23	2.04	0.00	2.46
South Devon (SD)	1.55	2.62	4.22	2.64	3.25	3.04	1.98	2.06	3.74	1.65	2.46	0.00

when crossed. Expected percent heterosis for cow fertility, birth weight, survival to weaning, and weaning weight was computed according to the procedure outlined by Roughsedge and others (2001). Table 8 provides the expected heterosis percentage for cow fertility observed in F_1 females. Similarly, Tables 9, 10, and 11 provide the expected heterosis percentage for birth weight, survival to weaning, and weaning weight, respectively.

Summary

Selection of appropriate breeds for a particular production system can be a challenging task. Consideration during the selection process should be given to a number of criteria (Greiner, 2002) including:

- climate (frost-free days, growing season, precipitation),
- quantity, quality, and cost of feedstuffs available,
- production system (availability of labor and equipment),
- market end points and demands,
- breed complementarity, and
- cost and availability of seedstock.

The selection of breeds and the genetics they contribute to the cowherd can have a large impact on profitability through the aggregate effects on each of the above criteria. Clearly, breeds need to be selected to fit a specific production system, whether that is selling replacement females, weaned feeder calves, or carcass components. For most producers, that production system should employ a structured crossbreeding system that utilizes two or more breeds. The breeds (and/or composites) chosen should produce calves that are appropriate for the market targeted. Moreover, the system and breeds included should provide a mechanism for the use of crossbred cows that are matched to the production environment in terms of mature size and lactation potential so as to capture the benefits of maternal heterosis. Selection of breeds that are too large and/or produce too much milk for the forage environment in which they are expected to produce may result in lower reproductive efficiency and increased supplemental feed costs. Selection of breeds provides an opportunity for the beef producer to impact both additive and non-additive genetics of the cowherd. Optimization of these two genetic components requires a disciplined approach to breed selection.

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