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Crossbreeding the Forgotten Tool

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CROSSBREEDING THE FORGOTTEN TOOL

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INTRODUCTION

Most ranchers know crossbreeding can increase output, but perhaps, don't appreciate the potential 25% crossbred advantage in lifetime productivity of crossbred cows. Yes, you read that correctly; 25% crossbred advantage in lifetime productivity. In recent years many commercial cow herds have changed dramatically as producers have opted to repeatedly top-cross Angus bulls on their commercial cows resulting in loss of heterosis and loss of complementary breed effects. Some of the reasons for this shift are; 1) a desire to simplify breeding programs (perception that crossbreeding systems are too complex), 2) use of black hide color as a proxy for market quality, 3) the belief that high percentage purebred commercial cattle produce more uniformity and consistency, 4) effective marketing of the Angus EPD's and carcass database, and 5) the Angus brand (CAB) impact (desire to get away from marketing commodity products).

A number of textbook crossbreeding systems are not "rancher friendly" in terms of management ease even though they deliver maximum heterosis. Additionally, dealing with grazing rotations, labor constraints and variable market targets require tough decisions that may tilt the crossbreeding system away from the original plan. Utilization of heterosis and breed differences in a crossbreeding system must be coupled with common sense ranch management in such a way that optimum (not maximum) heterosis is produced. There are some simplified crossbreeding systems that can meet this need very well.

Ranchers would be wise to crossbreed even if heterosis was zero, due to the complementary effects of matching strengths of one breed to offset weaknesses of another breed. The opportunity to mate bulls and cows of different breeds or paternal / maternal lines to take advantage of complementarity is an important part of the total crossbred advantage. Just think back 40 years to what the Angus x Hereford cow did to match up the strengths of those two breeds and mask some of the weaknesses of each; that was complementarity!

The formation of composite breed types based on a multi-breed foundation is an attractive alternative to traditional crossbreeding systems. Composite breed types are based on matings among crossbreds of two or more breeds. Once a composite is formed, it can be managed as a straightbred in a one-pasture system with none of the problems associated with small herd size or fluctuation in breed composition.

DOMINANCE GENE ACTION PRODUCES HETEROSIS

Heterosis (hybrid vigor) is measured as the performance advantage of crossbreds over the average of their straightbred parents. Occasionally, crossbreds will perform better than either parental breed, however heterosis should be measured against the average of the parental breeds. Heterosis can impact many traits, but is especially useful in improving performance in lowly heritable traits, such as, reproduction, early growth and fitness or lifetime productivity as shown in Table 1.

Table 1. Average Heterosis in Beef Cattle Traits

Trait	% Heterosis
Calf Crop Weaned	8
Wean Wt	13
Yearling Wt	4
Carcass Traits	3
Lifetime Productivity	25

On the other hand, highly heritable traits (above 40% heritability like some carcass traits) respond best to direct selection.   Response to selection is due to additive gene action, thus the expression of a trait adds up in proportion to the number of beneficial genes. However, the variation in lowly heritable traits is accounted for mostly by dominance gene action and to a lesser extent by epistasis or gene interaction. The result of dominance gene action is the heterozygous gene pairs are superior to the homozygous gene pairs.

HETEROSIS = RECOVERED INBREEDING DEPRESSION

Maximum heterosis is realized in the first cross of distinctly different breeds. Subsequent backcrossing to either parental breed (such as in a rotational crossbreeding system) will reduce the expected amount of heterosis realized. Backcrossing to either parental breed will increase the level of inbreeding and thus reduce heterosis. Inbreeding (mating of related individuals, such as half-sibs) will "fix" more homozygous gene pairs and generally result in depression of production, particularly so in reproduction and fitness traits. Since all breeds are slightly inbred, the level of heterosis found in breed crosses is, in reality, due to the recovery of accumulated inbreeding depression.

The largest and most dramatic expression of heterosis is found in crosses between bos indicus (Brahman) cattle and bos taurus (European origin) cattle because they do not share any recent common ancestors.

Much effort has been devoted to research on developing inbred lines within a breed for the specific purpose of crossing them to generate line-cross heterosis. This research has failed to produce any useful heterosis between inbred lines within a breed other than to barely offset the initial losses due to inbreeding depresssion.

THE POWER OF MATERNAL HETEROSIS

Heterosis can be partitioned into three components; 1) individual heterosis, that found in crossbred calves, 2) maternal heterosis, that found in crossbred cows, and 3) paternal heterosis, that found in crossbred sires. By far, the most important of these is maternal heterosis, accounting for about 2/3 of the total crossbreeding advantage. Maternal heterosis has more impact because of the effect on reproductive performance through earlier puberty, higher conception rate, faster breed back, greater longevity and the maternal impact on calf performance. Individual heterosis generally accounts for the other 1/3 of the potential 25% increase in lifetime productivity and is realized due to early vigor resulting in more live calves plus greater early calf growth rate. Paternal heterosis does exist in mating ability but is rarely measured unless crossbred bulls are exposed to high numbers of cows (40 cows or more) in the breeding pasture. If bulls are only exposed to 25 cows and they are all pregnant, crossbred bulls have no opportunity to demonstrate their advantage in mating ability beyond changing the calving distribution. Most ranchers would consider stretching their bull power in this manner as an unnecessary risk, thus paternal heterosis is rarely measured.

CROSSBREEDING SYSTEMS

Table 2. Shows the heterosis produced by a two-breed rotational crossbreeding system, a three-breed rotational crossbreeding, and a rotational terminal system using a third or fourth unrelated breed as the terminal. The total amount of the crossbred advantage (combination of heterosis and complementarity) is shown in Table 3.

Table 2. Heterosis in Traditional Crossbreeding Systems

Crossbreeding System	% Heterosis
2-Breed Rotation	67
3-Breed Rotation	87
Rotation Terminal	2X=67+100 3X=87+100

Table 3. Crossbred Advantage in Traditional Crossbreeding Systems

Crossbreeding System	% Crossbred Advantage
2-Breed Rotation	16
3-Breed Rotation	20
Rotation Terminal	24

Additional breeds could be added to increase heterosis, but there is a realistic limit to the number of breeds that can be used since the management complications multiply as the number of breeds increase. For example, rotational crossbreeding systems require the breeds used to be similar in major traits areas, such as mature size, calving ease, milk production, etc. The number of breeding pastures needed increase in proportion to the number of breeds used in the system. The sire breed identity of each replacement heifer is needed in order to mate those heifers to bulls of a different breed, thus avoiding backcrossing and optimizing heterosis.

One of the major drawbacks of rotational crossbreeding systems is the substantial swing in breed composition that occurs between generations and also between years. Since two or more breeds of purebred bulls are used within a year, the resulting variation in breed composition is the primary reason that crossbreeding is perceived to result in more variation than straight-breeding programs. Table 4 shows a three breed rotation program and the resulting breed composition for the three breeds. The average % breed composition hides the fact that there is large variation in breed composition from generation to generation, thus making it extremely difficult to assemble load lots of calves that are uniform.

Table 4. Breed Composition of a Three-Breed Rotation

		% Breed Composition		
Generation	Breed of Sire	Breed A	Breed B	Breed C
1	A	50	0	50
2	B	25	50	25
3	C	12	25	62
4	A	56	12	31
5	B	28	56	16
6	C	14	28	58
Average %		31	29	40

Rotational-terminal crossbreeding systems are extremely effective in gleaning heterosis from a two or three-breed rotation to produce replacements and young crossbred females that are mated to terminal sires once they reach 5 or 6 years of age. Such a system harvests heterosis and the important other half of the crossbreeding advantage, namely complimentarity of breed differences. One of the drawbacks of rotational-terminal systems is they don't fit small herds of cows. A three- or four-bull herd (90 to 120 cows) would be the minimum number needed to make a rotational-terminal system work. Obviously, if artificial insemination was used, some of the management and herd size considerations could be eased.

BREED EFFECTS ARE LARGE

A brief review of breed differences and biological types based on Germ Plasm Evaluation research at the Meat Animal Research Center (MARC) clearly shows within-breed, as well as between-breed differences, are large and that there is much overlap of trait distributions between breeds. However, it is also clear that breed means are truly different and the success (or failure) of crossbreeding programs may be decided when the choice of breeds is made for the foundation.

Table 5. Breed Group Efficiency of Gain To Different Endpoints (grams/mcal me)

Breed	Time	Carcass Wt.	Retail Product Wt.	Marbling
Red Poll	35	48	28	51
Angus	35	49	26	54
Limousin	47	54	57	47
Gelbvieh	40	49	49	45
Simmental	38	52	46	49
Charolais	40	53	50	49
MARC 1	39	51	45	48
MARC 2	37	52	37	52
MARC 3	35	50	30	53

Time=207 d, Carcass Wt. =734#, Retail Product Wt = 463#, Marbling = 4.0small

Table 5. Points out the opportunity for breed complementarity in efficiency of British and Continental breeds when fed to either a time, carcass weight, retail product weight or marbling constant slaughter endpoint. Note the change in breed ranking for efficiency of gain at the different endpoints. British breeds are more efficient when fed to a marbling constant endpoint and Continental breeds are more efficient when fed to a time,carcass weight or retail product constant endpoint. The MARC II composite (1/4 each Angus:Hereford: Simmental:Gelbvieh) provides the best complementary fit for efficiency of gain to both a marbling and carcass weight constant endpoint.

Also, research at MARC on efficiency of feed use in nine purebred breeds of cows indicates breeds that excel at low levels of dry matter feed intake (generally the British breed types) lack the productivity (growth and milk production) to excel at high dry matter feed intake. Likewise, highly productive breeds (generally the Continental breed types) are the least efficient when limited to low levels of dry matter feed intake. Thus, fitting these major breed differences to the carcass targets for progeny and to the feed environment for cows is critical to the success of crossbreeding programs.

CROSSBREEDING WITH COMPOSITES

While hybrids and composites are both crossbreds, hybrids are generally considered to be F1 or first crosses of purebred parents and composites are the result of matings among crossbred parents. The composite seedstock breeder must take special care to plan the formation of the composite to avoid inbreeding, thus a “closed composite” requires a large herd size, estimated at 25 sires per generation to hold inbreeding to less than .5% per generation. A composite seedstock breeder that uses an “open composite” approach has a much lower requirement for herd size since new sires (and perhaps breeds) are continually being evaluated and introduced, probably via AI, thus holding the inbreeding level to a minimum. Existing breeds of cattle are mildly inbred lines and to the extent that heterosis is due to dominance gene effects, heterosis is the recovery of accumulated inbreeding depression, thus managing inbreeding in composite breed formation is critical to success.

Table 6. Example Crossbreeding Systems

Crossbreeding System	Minimum % Breed A	Maximum % Breed B	Percent F1 Hybrid Vigor
Rotate Purebred A & B bulls	33	67	67
Rotate Purebred A, B & C bulls	14	57	86
Rotate F1 AxB and F1 CxD bulls	17	33	83
Composite AxBxCxD bulls	25	25	75
Composite AxB bulls	50	50	50
Composite A x (BxC) bulls	50	50	63
Rotate F1 AxB and F1 AxC bulls	50	50	67

Composite breed types do not sustain as high of level of heterosis as do the traditional rotation crossbreeding systems as seen in Table 6, however composites do allow for more complementarity between breeds. Several examples are shown in Table 6 that level the contribution of a given breed (Breed A in this example) or several breeds. Table 7 demonstrates the impact of the number of breeds and the impact of equal contribution of each breed to the foundation generation. The number of breeds used in the foundation of a composite accounts for most of the heterosis retained, however the heterosis is reduced as the contribution of each breed to the foundation is less than equal. Heterosis retained is proportional to the heterozygosity retained in a cross and is equivalent to (n-1/n), where n = the number of breeds. So a four-breed composite would produce 75% heterosis and that level would be maintained over time. The initial loss of heterosis is due to loss of heterozygosity which occurs between the F1 and F2 generations but is maintained in subsequent generations of crosses in a composite.

Table 7. Composite Heterosis By Mating Type

Number of Breeds	Breed Foundation	% Heterosis	% Crossbred Advantage
2	1/2:1/2	50	12
	5/8:3/8	47	11
	3/4:1/4	38	9
3	1/2:1/4:1/4	63	15
	3/8:3/8:1/4	66	15
4	1/4:1/4:1/4:1/4	75	17

Some breeders have assumed that variation in composite populations is greater than that found in purebred populations, however in a definitive study of the three composite lines at MARC and their parental purebreds, there was no significant difference in the coefficient of variation for reproduction, production or carcass traits measured (Table 8).

Table 8. Coefficients of Variation For Purebred vs. Composite Steers

Trait	Purebreds	Composites
Birth Wt.	.12	.13
Wean Wt.	.10	.11
Carc. Wt.	.08	.09
Retail Product %	.04	.06
Marbling	.27	.29
Shear Force	.22	.21

Another criticism that has been leveled against composites is they lack the accuracy of EPD's found in many purebred breed evaluations. This points out the need for multiple breed evaluation to be expanded between the most widely used breeds in commercial production.

Recently (Fall 2005) the Gelbvieh, Brangus, Limousin, Salers and Red Angus associatons have created a new company, Performance Registry Services. The goal of this joint venture is to provide commercial producers with National Cattle Evaluations by delivering a single suite of EPD's for all the participating breeds on a single base. This joint venture of breed associations will provide Total Herd Reporting of all cattle regardless of breed combination and data processing for all their members, while allowing for individual breeds to maintain their own identity. Along with the multi-breed EPD's there will be decision support software, search engines and a centralized data warehouse for commercial producers to use these tools. The result of this effort will be to make it easier for producers to evaluate breed inputs into crossbreeding programs.

The commercial user of composite breed types has to worry about few of the constraints that the composite seedstock breeder encounters, as they can be managed as a straightbred in a one-pasture system. Composite breeds offer the opportunity to use genetic differences among breeds to achieve and maintain the performance level for such traits as climatic adaptability, growth rate and mature size, carcass composition, milk production, and fertility that is optimum for a wide range of production environments and market scenarios. Further, composite breeds may provide herds of any size an opportunity to use heterosis and breed differences simultaneously.

Composites offer an opportunity to counter the antagonism between USDA Quality Grade and Yield Grade as shown in Table 9. The often stated goal of the beef industry is to produce finished cattle that are at least 70% USDA Choice or better, 70% Yield Grade 1 & 2 and have zero defects or zero "out" cattle. This 70-70-0 target is difficult to achieve with either British or Continental breeds alone, however a blend of these two types as found in the MARC II (1/2 Continental:1/2 British) does a much more acceptable job of meeting the 70-70-0 target. Thus a composite can actually lower the risk of non-compliance to a market target.

Table 9. Conformance of Breed Types to Carcass Targets

	Breed Type				
Item	British	Continental	Marc I	Marc II	Marc III
% Y 1&2	38	89	83	56	53
% CH +	70	30	43	55	66
	% Non-Conformance To 70 – 70 – 0 Target				
Yield Grade	32	0	0	14	17
Quality Grade	0	40	27	15	4
Total	32	40	27	29	21

Careful selection of foundation sires used in the development of a composite can further move a herd toward meeting market targets. Table 10 shows six lots of steers born at the Gudmundsen Sandhills Laboratory near Whitman, Ne. which were sired by bulls produced in the University of Nebraska Teaching herd. Unlike the MARC Germ Plasm Utilization project where bulls were sampled across a broad spectrum of each breed, the foundation sires in the UNL Teaching herd were selected using EPD's to be above average in calving ease, average in milk production, average or below in mature size, and above average in marbling and other carcass traits. The result is steers on average that are 87% USDA Choice or better and 66% Yield Grade 1 & 2. Several of the individual lots of cattle quite easily surpassed the 70-70-0 market target.

Table 10. Calves sired by University of Nebraska Composite bulls.

Date	#	Wt.	Fat	REA	YG	%Y1:2	%Ch
6/05	37	836	.54	13.2	3.19	49	97
5/05	45	823	.57	13.8	3.02	49	84
0/05	89	795	.51	13.5	2.83	62	85
3/05	22	802	.41	14.6	2.34	82	91
3/05	24	729	.49	13.0	2.74	75	96
12/4	53	809	.40	14.5	2.35	89	81
AV.	270	802	.49	13.8	2.77	66	87

SUMMARY

Heterosis and complementarity are powerful forces that combine to produce the total crossbred advantage of beef cattle crossbreeding. This crossbred advantage can amount to as much as 25% greater lifetime productivity (pounds of calf weaned per cow exposed) for crossbred cows as compared to straightbred cows. Some commercial cowherds have drifted towards straightbred Angus herds in an attempt to achieve management simplicity, greater uniformity in their cattle, and to pursue a premium (non-commodity) product. The result of this shift is the loss of most of the heterosis that once existed in many of our commercial cowherds.   Loss of heterosis shows up in the same lowly heritable traits that would be associated with inbreeding depression, namely reproductive, fitness and longevity traits. Thus, the price paid for loss of heterosis occurs as a number of very small losses that when added up can amount to a substantial sacrifice in lifetime productivity (25%).

Traditional crossbreeding systems (rotations & rotation-terminals) are very efficient in maximizing heterosis but are more complex than many producers would like. Perhaps the availability of estrus synchronization protocols for timed AI will assist some commercial producers in using some of the traditional crossbreeding programs in the future. One-pasture crossbreeding programs exist that can deliver adequate (not-maximum) heterosis, are simple to manage, utilize breed differences (complementarity), can be designed to produce uniform calf crops and can help avoid several important genetic antagonisms.   Composite breeds must be carefully formed with the same attention to breed choices and sire selection that is used in straightbreeding programs. However, once formed the commercial user of composites can manage a composite crossbreeding program with greater management ease than traditional crossbreeding systems. One-pasture crossbreeding programs offer commercial producers a practical tool to enhance management effectiveness and increase profitability.