CROSSBREEDING IN BEEF CATTLE

by 680

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INTRODUCTION

There are basically two breeding plans that are used by the stock-man in livestock breeding. These are inbreeding and outbreeding. All breeding programs can be classified in varying degrees under one of these. Inbreeding is the mating of animals more closely related than average, while outbreeding is the mating of animals less related than average. Inbreeding programs tend to produce increased genotypic and phenotypic diversity.

This report is concerned with the effects of crossbreeding. Cross-breeding is a breeding plan classified under outbreeding, and involves the crossing of different breeds within a species or of different inbred lines within a breed.

Some past and present examples of crossbreeding are:

The crossing of improved English bulls and native Texas longhorn cattle to improve the meat production and quality of the Texas cattle. Presently, virtually all of the poultry, both layers and broilers, are produced by crossing inbred lines or breeds. The swine industry is also making use of crossbreeding to a large extent in the commercial production of market hog and breeding gilts. Hybrid corn is still another example of the cross-ing of inbred lines.

Much interest has developed lately in regard to crossbreeding in beef cattle. Although not as complete as in some other species of farm livestock, a good deal of research data is available on the effects of crossbreeding in beef cattle.

This report is a summary of reports on crossbreeding research within the United States and Canada and particularly within the Regional Project NC-1, "Improvement of Beef Cattle Through Breeding Methods." The states within this region with crossbreeding test in progress are Missouri, Nebraska, and Ohio.

Because of the long generation interval, low number of offspring per animal and the large financial investment involved, all the questions concerned with crossbreeding beef cattle can not be answered quickly. Thus, this report will not yield definite answers for all the questions concerning crossbreeding in beef cattle, but represents an attempt to explain the genetic basis for crossbreeding, presents a summary of the results of some of the crossbreeding research conducted to date, and suggests methods by which crossbreeding may be used to improve beef production.

GENETIC BASIS FOR CROSSBREEDING

The term crossbreeding is used rather braodly in reference to various types of animal outbreeding. Lasley (1963) and Rice et. al., (1957) give the following information as the genetic base for crossbreeding. Outbreeding is a breeding system that involves the mating of animals less closely related than the average of the group to which they belong. Breeding systems classified under outbreeding include crossbreeding, outcrossing, grading up, the crossing of inbred lines, and crosses between animals of different species.

Species hybridization is practiced in the crossing of horse and ass to produce the mule, which is the most common example of this type of outbreeding. Other examples are the hinny (stallion X jennet), the zebroid (zebra X horse), and the cattalo (bison X domestic cow). A characteristic of species hybridization is a high incidence of impared fertility or sterility among the offspring. This impared fertility or sterility is due in most cases, to differences in chromosome numbers or physiological differences.

As has already been mentioned, the best example of commercial crossing of inbred lines in animals is in the production of poultry, both broilers and layers.

Grading up is the practice of breeding purebred sires to inferior females generation after generation in order to increase the merit of grade herds. The usage of breeds of English bulls on Texas cattle was an example of this type of outbreeding.

Crossbreeding refers to mating unrelated animals within the same breed. This is the breeding plan that is used by most commercial and purebred beef producers who have only one breed of cattle in their herd.

Crossbreeding is the mating of animals of the same species but of different breeds. This is the type of breeding plan discussed in this report.

There are three basic reasons for crossbreeding in beef cattle. These are to take advantage of heterosis, to take advantage of the good qualities of two or more breeds, or to form a new breed.

Heterosis of hybrid vigor is the production superiority that is exhibited by crossbred offspring over that of their parents or of straight bred offspring from the same parental stock. The measurement of heterosis will be discussed later. Heterosis is the main reason for crossbreeding in beef cattle as well as in poultry and swine. The production of hybrid corn is an example of heterosis being utilized on a wide scale commercially.

Crossbreeding and species crossing are also practiced to take advantage of the good qualities of two or more breeds. This is the reason that beef breeders in the Southern United States cross Brahman and English cattle. This results in fertile species cross which has some of the heat tolerance of the Brahman cattle as well as the carcass qualities of the British breeds. Another example of this is the crossing of the fine wool and long wool breeds of sheep to produce a vigorous crossbred lamb that possesses growthability, desirable carcass traits and a gregarious nature for range adaptability.

The third basis for crossbreeding is to develop new breeds. This is the program the King Ranch used to produce the Santa Gertrudis breed from the Brahman and Shorthorn. The Columbia and Targee breeds of sheep were produced by similar methods. All of the American breeds of swine except the Berkshire, Yorkshire, and Tamworth have been formed by crossbreeding. The breeding programs to form these new breeds are somewhat different than the normal crossbreeding program since they are aimed at developing animals with a certain predetermined percent ancestory. These animals are then perpetuated on a within breed basis thus keeping their ancestory at a certain fixed level.

As has already been mentioned, heterosis or hybrid vigor is the term given to the increased vigor of the crossbreeds over its straight-bred parents. An animal's genetic potential is inherited by one or both of two general types of inheritance. These two types are referred to as additive and non-additive gene action. Additive gene action involves many pairs of genes influencing a trait. Because of the large number of genes per trait, there is no sharp distinction between pheno-types. This is the type of inheritance which causes the offspring to equal the average of the parents when environmental and random variation is accounted for. This variation cannot be adjusted in an individual mating, but can be estimated as an average in a large number of matings. Production traits which are determined by additive gene action are those traits possessing higher heritability values since the phenotype is a better indicator in an animals genotype than is the case with non-additive inherited traits. This allows the breeder to pick superior animals genetically on the basis of

phenotype, because they tend to transmit genetically according to phenotypic merit.

The following chart illustrates a very simple example of additive gene action involving only two pairs of alleles.

TABLE I   ADDITIVE GENE ACTION

Generation	Black Hair AABB	X	White Hair aabb
P_1			
F_1		Roan AaBb	
F_2			

	Genotype	Phenotype
1	AABB	Black hair
2	AABb	Dark roan (more black than white)
2	AaBB	Dark roan (more black than white)
1	AAbb	Roan (equal black & white)
4	AABb	Roan (equal black & white)
1	aaBB	Roan (equal black & white)
2	Aabb	Light roan (more white than black)
2	aaBb	Light roan (more white than black)
1	aabb	White hair

Non-additive gene action usually involves inheritance due to one or only a few pairs of genes. This type of inheritance produces a sharper distinction between phenotypes than does additive inheritance. In general traits inherited by non-additive gene action are lowly or moderately *heritable with environment and random variation playing a large part in* determining the phenotype.

A list of the most common production traits in beef cattle and their heritabilities are as follows:

TABLE II

Heritability Estimates

(NC-1 Regional Publication 120)

Trait	Heritability percent
Calving interval	10%
Birth weight	40%
Weaning weight	30%
Cow maternal ability	40%
Feedlot gain	45%
Pasture gain	30%
Final feedlot weight	60%
Conformation score:	
Weaning	25%
Slaughter	40%
Carcass traits:	
Grade	40%
Rib eye area	70%
Fat thickness	45%
Retail product (%)	30%
Retail product (lbs.)	65%

The genetic basis for the increased vigor or heterosis that is exhibited by crossbred offspring over their parents is due to non-aditive

gene action. There are three types of non-additive gene action that are responsible for heterosis or hybrid vigor. These three types are dominance, overdominance, and epistasis.

Normally several to many pairs of genes affect back production traits. Under a condition of dominance, one gene of an allelic pair will mask the effect of the other or recessive gene in the heterozygate. When two animals from a closed breed are crossed they may have either homozygous dominant or recessive allelic genes. This may be due to some degree of within breed selection which tends to increase the frequency of certain genes. When the homozygous parents are crossed they may produce a heterozygous individual. Since some of the genes the offspring possesses are dominant, producing the dominant phenotype even when heterozygous, the offspring may be superior over all to either or both of his parents. An example of dominance involving only one allelic pair of genes would be as follows:

TABLE III

DOMINANCE

Assume	No environmental effect genotype AA = 520 lbs. adjusted weaning wt. genotype Aa = 520 lbs. adjusted weaning wt. genotype aa = 480 lbs. adjusted weaning wt.
Mate	AA male X aa female (520#) (480#) adjusted weaning wts.
F_1	all Aa 520 lbs. adjusted weaning wt.

Another reason for F_1 superiority due to non-additive gene action is overdominance. In the overdominance condition the heterozygote possesses a phenotype which is superior to the homozygous dominant or homozygous recissice. As with complete dominance several pairs of genes with overdominance action may affect the same trait. The ideal condition for maximum heterosis in the F_1 under overdominance would be the mating of two individuals having genes which would combine to form a completely heterozygous F_1 such as a homozygous dominant male and a homozygous recessive female. An example of overdominance is as follows:

TABLE IV

OVERDOMINANCE

Assume			No environmental influence
Genotype	AABB	produces	500 lbs. adjusted weaning wt.
Genotype	AaBb	produces	525 lbs. adjusted weaning wt.
Genotype	aabb	produces	485 lbs. adjusted weaning wt.

Mate	AABB male (500#)	X	aabb female (485#)
	adjusted weaning wt.		
F_1	all AaBb	525 lbs. adjusted weaning wt.	

Both overdominance and dominance are involved with allelic pairs
of genes. The third type of non-additive gene action is epistasis or
interaction between genes which are non-alleles. This includes classical
epistasis and complementary gene action. A gene exhibiting classical
epistasis covers up or masks the effects of another non-allelic gene.
This type of gene action can produce a wide variety of phenotypes depending
on the degree of epistasis between non-alleles. Epistatic genes may have
a positive or negative effect on an animals genotype. An example of
epistatic gene action is as follows:

TABLE V

EPISTASIS

Assume   No environmental influence

Gene A is dominant to a and positive epistatic to B and b,
It produces a 500 lbs adjusted weaning wt.
Genotype aaBB, aaBb, produce adjusted 450 lbs. adjusted weaning wt.
Genotype aabb produces a 425 lbs. adjusted weaning wt.

Mate   AABB male   X   aabb female
            (500#)   (425#)

F₁   AaBb = 500 lbs. adjusted weaning wt.

As can be seen from these examples crossbreeding tends to produce
a heterozygous individual, due to the lower than average relationship of
the parents. This heterozygosity tends to cover up or mask the effects of

the recessive genes that were present in the parents and produce a hybrid which possesses a superior phenotype. In actual cases, crossbreeding involves several or all of these non-additive gene effects with a large number of genes affecting the beef cattle production traits. In addition to the genetic potential of an individual, the phenotype of an individual is affected by the environment and random variation as well as interaction between genotype and environment. Thus it can be seen that the genetics involved in crossbreeding is quite complicated and the method of inheritance of any one trait can not be determined in an absolute fashion. Also to be taken into consideration is the fact that the hybrid offspring will not breed true when they are crossed but will instead produce a variety of genotypes due to their heterozygous genotypes.

DETERMINATION OF DEGREE OF HETEROSIS

As has been stated traits that respond to crossbreeding are inherited in a non-additive manner, however not all traits are inherited in this manner or in the same degree. Highly heritable traits are affected the least by crossbreeding and lowly heritable traits the most since lowly heritable traits are inherited in a non-additive manner with a heterozygous animal having a superior phenotype. Traits decreased the most by inbreeding are increased the most by crossbreeding since inbreeding is just the opposite of crossbreeding, producing a more homozygous animal. Also traits expressed early in life seem to be affected the most by crossbreeding. Traits affected by heterosis are also influenced to a good degree by environment. The degree of heterosis also depends upon the genetic diversity of the parents, since unrelated parents are less likely to be homozygous for the

same pairs of genes. This will be demonstrated in literature reviewed for this report, in comparisons of British X British and British X Brahman crosses.

Another factor to be taken into consideration is that heterosis can not be accurately estimated for a single cross, but is instead an average of many crosses, with the average heterosis for each trait varying from test to test. This variation is due to the different genotypes which result from each single cross, as well as variation both random and environmental which occurs from one location and management system to the other. In fact, the environmental and random variation may be responsible for a much larger percent of the variation between animals than are the animals gneotypes. Because of this management systems are carefully explained for each test and environmental variations such as age, year, and sex are adjusted for.

METHODS OF ESTIMATING HETEROSIS

There are two methods for estimating the average superiority or hybrid vigor exhibited by crossbred offspring. The first of these methods is to compare the crossbred F_1 generation to the parental breed with the highest average. This can be represented in the formula form as:

$$\text{Percent Heterosis} = \frac{F_1 \text{ crossbred mean} - \text{Mean of superior parent breed}}{\text{Mean of superior parent breed}} \times 100$$

An example using this formula would be:

TABLE VI

HETEROSIS BASED ON SUPERIOR PARENT

Hereford   X   Angus

F_1 adjusted weaning wt.	550 lbs.
Hereford breed adjusted average wt.	535 lbs.
Angus breed adjusted average wt.	530 lbs.

Percent heterosis of offspring = $\dfrac{550-535}{535}$ X 100 = 2.8%

The other method used for expressing percent heterosis is to compare the crossbred superiority to the average of the parental breeds. This can be represented in formula form as:

$$\text{Percent Heterosis} = \frac{F_1 \text{ crossbred mean} - \text{Parental breeds mean (mid-parent)}}{\text{Mean of parental breeds (mid-parent)}}$$

Using the same weights as in the preceeding example the percent heterosis would be:

$$\text{Percent Heterosis} = \frac{550-532.5}{535.5} \times 100 = 3.3\%$$

As these examples illustrate the percent heterosis is higher (using the same data) when computed by the second method as a percent advantage over the parental averages. This method is used most commonly since it provides a more accurate measure of the actual amount of heterosis. In order for a trait to be due to non-additive gene action and respond to heterolic effects it must be above the mid-parent average when adjustments for environmental and random variations have been made.

A trait due to additive gene action alone would cause the F_1 average to be equal to the average of the parental breeds. Using the superiority of the highest parental breed average ignores part of the non-additive genetic variation.

After considering the general genetic principles involved in cross-breeding some theoritical statements on the effects of crossbreeding can be made. These are: (1) lowly heritable traits should show the most heterotic response in crossbreeding programs; (2) crosses between widely divergent parents should show more heterosis than the crosses between more closely related individuals; (3) heterosis can not be reliably estimated from any single cross but must be stated as an average percent heterosis of a breed cross based on numerous trials because much of the variation is due to animal samples, environmental and random variation, and ; (4) heterosis is exhibited when an animal is superior to the average of its mid-parent.

LITERATURE REVIEW

The following literature review is a summary of the results of beef cattle crossbreeding research in the NC-1 Regional Beef Cattle Breeding Project as well as some research done in Canada and various states outside of the North Central Region. There is much variation among these trials concerning breeds, management and climate. These differences will be pointed out throughout the review. Also, percent heterosis, or the advantage of crossbred offspring, is evaluated in several different manners, consequently, close attention must be paid to the way that heterosis is computed in the comparison of various test results. The review is divided so that each production trait and heterosis effect upon it is discussed separately starting with reproductive efficiency through carcass traits.

BREEDING EFFICIENCY

One of the most important factors that determines whether the commercial cow herd shows a profit or loss is the reproductive performance of the cows in the herd. This trait is lowly heritable (10%) and consequently non-additive genetic variance and environmental factors are largely responsible for the variation in this trait.

Crossbreeding in swine has shown that heterosis has a pronounced effect on this trait and consequently increased reporductive efficiency is one of the main reasons for crossbreeding in swine. However, in cattle the situation is a little different than in swine. Since the cow is a monotocus species while swine are a polytocus species. Because of this the improvement from

heterosis in beef cattle must be exhibited in increased reproductive efficiency on an individual.

The University of Nebraska has conducted a beef cattle crossbreeding experiment for five years from 1963 thru 1967. Breeds used in this test were Hereford, Angus, and Shorthorn and their recriprocal crosses. Cundiff et. al., (1965) reported findings on the first phase of this test. There was a 3 percent advantage in percent of crossbred calves weaned over the average of the parental breeds. In the second phase of the experiment now in progress Cundiff et. al., (1968) reported that heterotic effects for weaning weight are being evaluated in a three way cross through use of crossbred cows. Calves from the three way cross are compared to calves from the crossbred cows, straight bred half sisters. Both the crossbred and straightbred cows are bred to the same bull. This produces straight bred and crossbred calves which are 31.25 percent related. Heterosis for percent calf crop weaned using this breeding system has been 17, 6, 10, -3, and 11 percent respectively for years from 1963 through 1967. This gives an average heterosis of 8 percent. It should also be noted that there is a good deal of variation between years which is assumed to be due to environmental effects.

The Missouri heterosis experiment reported by Comfort and Lasley (1968) involved Charolais, Angus, and Hereford breeds. Overall percent heterosis average for six years for percent crossbred calf crop born was 3.1 percent. This advantage varied from 4.9 percent for Charolais X Angus crosses to -0.2 percent for Angus X Hereford crosses. There was a large variation between breeds with Charolais being the lowest at 73.9 percent and Hereford the highest at 91.7 percent. Percent heterosis for

weaned calf crop was not included in data from this test. Comparisons between breeds, including both straightbred and crossbred calves from each breed of percent calf crop born and percent calf crop weaned were made however. These figures were 77.3 percent for Angus for percent calf crop weaned per cow bred, 83.2 percent for Herefords and 86.4 percent for Charolais. More information concerning factors affecting heterosis percent for percent calf crop weaned will be discussed in the section on birth weight.

Ohio crossbreeding research reported by Klosterman et. al., (1968) has in general agreed with the Nebraska and Missouri data. These tests involve a breeding herd of straightbred, non-registered Herefords and three quarter and higher percentage Charolais cows. Three calf crops were include- in this experiment with matings made to produce equal numbers of Charolais, Hereford, and recriprocal crossbred calves. Calving percentages at birth were 89 percent for crossbreds and 86 percent for straightbred matings. Weaned calf percentages were 77 percent for crossbreds and 76 percent for straightbreds. The Charolais appeared to wean a smaller percent of calves than Herefords when bred to produce straightbred calves but a higher percent of crossbred calves.

Work on heterotic effect on calving percent conducted outside of the NC region are as follows:

Turner et. al., (1968) reported on Louisiana trials with Angus, Brahman, Brangus, Charolais, Hereford, and Shorthorn cattle and their crosses over a five year period. Overall averages of crossbred calving percentages of crossbred cows was 9.6 percent over straightbred cows. All

groups of crossbred cows produced a higher calving percentage than the parental averages. No significant differences were found between straight-bred cows having straightbred calves and those having crossbred calves.

Gaines et. al., (1966) reports that in crossbreeding trials at the Virginia Ag. Exp. Station using 572 straightbred and crossbred matings of Herefords, Angus, and Shorthorn breeds and their crosses a 10 percent advantage in percent calf crop weaned in favor of crossbred matings was found. This indicated a heterosis effect for both cow fertility and livability of the crossbred calves.

Results of crossbreeding trials involving Brahman cattle have been conflicting to some degree on the heterosis effect on reproductive performance. Peters and Slen (1969) reported a Canadian trial involving Brahman bulls crossed on Hereford, Angus, and Shorthorn cows. The one-half Brahman, one-half British breed cows were then bred to Hereford bulls. No significant differences were noted among the crossbred cows in percent calf crop weaned over the straightbred Hereford cows.

This was also the case in S-10 (Southern) regional trials using Brahman and Brahman-British breed crosses. These trials were conducted in the gulf coast states where the use of Brahman cattle adapted to the hot climate has been necessary for profitable beef production. Results of these trials reported by Kincaid (1963) indicate the following results:

TABLE VII

INFLUENCE OF LACTATION STATUS ON FERTILITY
OF BRITISH, BRAHMAN, AND CROSSBRED COWS [a]

1952-1959

| | LACTATION STATUS WHEN BRED | | | | |
| | Lactating | | Dry | | Difference |
	No	% Calved	No	% Calved	% Wet-% Dry
British	9,833	82.1	4,612	71.5	10.6
British-Brahman	2,956	77.6	1,734	82.0	-4.4
Brahman	449	67.0	355	80.1	-13.1

a. Kincaid, C.M. Crossbreeding in the Southern Region, Crossbreeding in Beef Cattle.

As can be seen from Table VII British or Brahman cattle have had the best or poorest reproductive performance depending on their location status with crossbred cows being intermediate in both cases. The overall crossbred calving percentage shows a 6 percent heterosis advantage over the British and Brahman averages for both lactating and dry calving percentages. These varying calving percents seem to be due to the failure to ovulate and exhibit estrus in the young lactating Brahman or Brahman crossbred cow thus lowering calving percentage. Tests of this theory reported by Warnick (1966) have shown British cows to be 10 percent higher in fertility when lactating than

when dry, while Brahman females were 13 percent higher in fertility when dry as compared to lactating females. This difference is felt to be at least partially due to good milk production in the Brahman without adequate nutrition. Florida researchers feel that this can be overcome by strict culling and improved management. Reproductive efficiency in Brahman and native cross cows was raised from 42 to 93 percent for calving percent by culling open cows and heifers and establishing a breeding program in which one-half of the herd is being upgraded by Angus and Hereford bulls while the other one-half is being systematically crisscrossed between Hereford and Brahman or rotationally crossed between Angus and Santa Gertrudis.

LONGIVITY AND LIFETIME PRODUCTION

Another factor connected closely to reproductive efficiency, measured by calving percent on a herd basis, is the longivity and lifetime production of each individual cow. Since raising herd replacements is a costly production item, if cows could produce a larger number of calves before being replaced this would be a real advantage in reducing costs, and as a tool to increase selection pressure or replacement heifers. Only one literature report was located on this subject. Peters and Slen (1967) reported a long term test conducted at Lethbridge, Alberta, Canada in which crossbred cows were handled as a range herd. It represented Brahman, Hereford, Angus, and Shorthorn breeding. The crossbreds were superior in longivity and total lifetime production to the straightbred cows. Since the crossbred cows were not compared to their parental breed averages no heterosis percentages could be determined.

BIRTH WEIGHT

Birth weight of beef cattle is affected by heterosis. Its consideration is unlike weaning weight or post natal rate of gain because maximum birth weights are not always desired. The ideal birth weight would be one which would be as heavy as possible without causing an excess of calving difficulties.

Gregory (1968) reported that in Nebraska tests of 751 straightbred and crossbred calves of Hereford, Angus, and Shorthorn breeding the heterosis average for all crosses was +2.7 percent. In this test there was variation between breeds but the variation was not large enough to be significant.

In Missouri tests reported by Comfort and Lasley (1968) involving Charolais, Hereford, and Angus two year averages for all crosses were 74.2 pounds and 71.7 pounds for all purebreds, producing a birth weight advantage of 2.5 pounds for crossbred calves. Birth weights varied from 79.8 pounds for the Charolais and Hereford recriprocal crosses to 68.1 pounds for the Angus and Hereford recriprocal crosses. This crossbred birth weight advantage represents a 3.48 percent heterosis advantage.

This percent heterosis is an agreement with Montana trials with linecross Hereford cattle reported by Flower et. al., (1963) and again by Brinks (1967). Heterosis advantages for birth weight from these experiments were 1.0 percent and 3.0-3.8 percent respectively.

A summary of research prior to 1955 made by Holt (1955) lists an overall heterosis effect for birth weights of 3.0 percent for 22 published experiments up to that time.

In Texas trials, reported by Riggs, (1966) Brahman and Hereford

cross calves were lighter than straightbred Hereford calves at birth by 1.0 to 5.0 pounds. These same calves, however, outweighed the straight-bred Hereford calves at weaning by 10 to 70 pounds. Since this was the case, there was no real advantage to increased birth weights in this trial.

In Ohio trials reported by Klosterman et. al., (1968) Charolais claves were consistantly heavier than the crossbred and Hereford calves at birth. Heterosis exhibited by crossbred calves for birth weight was 1.0 percent and increased to 3.4 percent at weaning. Highly significan t relationships were found between weight of cow, weight of calf at birth, and weaning weights as well as final and carcass weights.

With the heterosis effect on birth weight, some calving difficulty was experienced particularly by Hereford heifers bred to Charolais bulls. Percent assisted births were Hereford X Hereford 11 percent, Charolais X Charolais 14 percent, Hereford bull X Charolais cow 6 percent, and Charolais bull X Hereford cow 33 percent. More than 80 percent of the total number of calving difficulties were first calf two year old heifers. Only limited calving problems were experienced following the first calf regardless of the breed or cross. In connection with calving difficulties although calving percent of both of the recriprocal crosses was 89 percent, weaned percent of calves for cows bred was 82 percent for Hereford sires and Charolais dams while Charolais sires and Hereford dams produced a 72 percent weaned calf crop per cow bred. This produced an average of 77 percent for the recriprocal cross in comparison to 76.5 percent for the straightbreds. These differences include embryonic mortality, loss at calving, and pre-weaning deaths. These dats suggest that the size and age of cows and the

size of bulls should be taken into consideration when setting up a cross-
breeding program.

PREWEANING GROWTH RATE

Preweaning growth rate is affected primarily by two factors: mothering
ability of dams and genetic potential for growth of the calf. Preweaning
growth rate is a complex trait to evaluate.

Mothering ability

In Nebraska trials reported by Cundiff et. al., (1968) mothering
ability of crossbred and straightbred cows was evaluated on the basis of
estimated milk production for a 12 hour period when calves were 2-3 months
of age and dams were on summer range. Crossbred dams during three years
showed a + .47 pound to + .84 pound advantage over straightbred dams in
milk production estimated per 12 hour period.

Kincaid, (1966) summarized crossbreeding research in the southern
states and reported that crossbred dams were superior to the straight
British and straight Brahman dams. Some of the production superiority of
crossbred dams was due to heterosis for growth rate expressed by calves.
It was noted however, that cows with Brahman blood were better mothers
than straight British dams. Due to pooling of data no set heterosis for
maternal ability could be determined. Increased mothering ability of
Brahman and Brahman cross dams was reported by Koger (1963) a Florida
trial in which first cross calves with British dams averaged five percent
advantage in weaning weight over straightbreds, while first cross calves with
Brahman dams averaged 12-15 percent heavier than the parental straightbreds.
In order of their weaning weight advantage, crossbred calves nursing
crossbred dams were heavier than or equal to crossbred calves nursing

Brahman dams which in turn were superior to crossbred calves nursed by British breed dams. These heterosis advantages all remained relatively high in subsequent generations when a systematic crossbreeding program was followed.

Growth rate of calf

Nebraska trials reported by Gregory (1968) with Hereford, Angus and Shorthorn straightbreds and their recriprocal crosses to produce two breed and three breed cross calves revealed the following results. Crossbred calves out of straightbred dams exhibited a 4.5 percent weaning weight advantage over straightbred calves. The largest advantage in 205 day weights was through the use of crossbred cows to produce three way cross calves. The advantage for a five year period in pounds of calf weaned per cow bred for crossbred dams over straightbred dams was 17,32,21,23 and 28 pounds respectively. When these weight advantages were averaged together a 5 percent advantage is noted in weaning weight in favor of crossbreeding.

When the percent heterosis advantage for both reproductive efficiency and calf weaning weight was combined in the Nebraska trials a 17 percent advantage in pounds of calf weaned per cow bred was realized for crossbred cows in a three breed cross. This did not include the 3.0 percent advantage in calf crop weaned and 4.5 percent advantage in weaning weight of two breed cross calves over straight bred calves.

In Ohio tests reported by Klosterman (1968) with Hereford and Charolais, the crossbred calf heterosis advantage for weaning weight was 3.4 percent. Average weights for the straightbreds and crosses were Hereford-518 pounds, Charolais-645 pounds, crossbred-602 pounds. Average weights for the straightbreds and crosses were

In Missouri trials, reported by Comfort and Lasley (1968) results of six calf crops of Hereford, Angus, and Charolais and their recriprocal crosses are as follows. Charolais and Angus crosses averaged 396.5 pounds which was 17.1 pounds above the parental breed average. Charolais-Hereford cross calves averaged 387.6 pounds which was 4.5 pounds above the parental breed average, and Angus-Hereford cross calves averaged 373.2 pounds and were 30.9 pounds above the parental breed averages. Heterosis for weaning weight varied from 1.2 percent for the Charolais-Hereford cross to 9.0 percent for the Angus-Hereford cross. Purebred 205 day calf weights averaged 338.5 pounds for Angus, 246.0 pounds for Hereford, and 420.2 pounds for Charolais. Straight Charolais were consistantly heavier than the crossbreds, but the Angus and Hereford crosses were heavier than other of the parental breed averages.

A Canadian test reported by Peters and Slen (1967) with crossbred cows of the Brahman, Shorthorn, Angus and Hereford breeds revealed the following results, which are very similar to Nebraska findings. Comparisons of crossbreds were made to straightbred Herefords, however no crossbred advantage can be listed as heterosis advantage in a strict sense. Brahman-English cross cows exhibited a 25 percent increase in Kilograms calf weaned per cow bred in a backcross and 64-87 percent increase in a three breed cross. As has already been discussed part of this large heterosis advantage may be due to the mothering ability of the Brahman crossbred dams.

In another Canadian test reported by Lawson (1964) with Hereford and Highland breeds and their recriprocal crosses, the Hereford-Highland crossbred calves were superior in weaning weight by 6.0 percent in comparison to the Hereford straightbreds and 12.6 percent in comparison

to the Highland straightbreds average. In general the Highland straightbred weaning weights were inferior in comparison to the Hereford.

Louisiana tests reported by Temple and Miller (1961) with Angus, Brahman, Brangus, Hereford, Charolais, Shorthorn and their recriprocal crosses showed a highly significant heterosis effect for 180 day calf weights. The actual percent heterosis advantage varied widely for different breed crosses.

In three Montana tests, reported by Flower (1963) with inbred Hereford in a linecross breeding program the linecross Herefords exhibited a heterosis advantage in comparison to inbred lines varying from 4.6 percent to 13.0 percent. Inbreeding percents were 20 to 30 percent for the inbred lines.

WEANING CONFORMATION SCORES

In Nebraska trials reported by Gregory et. al., (1968) with Hereford, Angus, and Shorthorn breeds the crossbred calves at weaning had conformation scores that averaged .17 grade higher than the straightbred calves. This was a small advantage but it was statistically significant for the 751 records.

In Missouri trials reported by Comfort and Lasley (1968) the Charolais, Angus, and Hereford crossbred calves showed a straight heterosis advantage. Charolais X Hereford cross heterosis advantage was .3 of a point. Charolais-Angus cross calves showed a heterosis advantage of .7 of a point. Angus and Hereford cross calves exhibited no heterosis advantages for weaning score.

Montana trials with inbred Herefords reported by Brinks et. al., (1968) revealed the greatest heterosis advantage for weaning score. Upon crossing five inbred lines used in the trials all produced linecross calves which exhibited from 2.5 to 2.7 percent heterosis for conformation score above the inbred calves. Inbreeding was at the 20 to 35 percent level in the inbred dams.

In a Florida crossbreeding trial with Brahman-Shorthand crossbreds, Kirk et. al., (1966) reported that from a total of 476 calves, calves out of crossbred cows (one-half Shorthorn X one-half Brahman) and sired by either Shorthorn or Brahman bulls had an average grade of good. Crossbred cows of .75 percent Brahman and .25 percent Shorthorn breeding backcrossed to a Brahman bull and crossbred cows of .75 percent Shorthorn and .25 percent Brahman breeding backcrossed to Shorthorn bulls produced calves also graded high standard. Straight bred Brahman calves also graded high standard while straightbred Shorthorn calves graded standard. These results tend to indicate a slight heterosis effect proportional to the genetic diversity of the parents involved in the cross.

<div align="center">POST WEANING GAIN</div>

Low energy ration

Ohio crossbreeding trials were designed so that one half of each year's calf crop were grown on a high energy ration while the other one half was maintained on a lower plane of nutrition. Klosterman (1968) reported that one half of the Charolais Hereford and recriprocal cross calves were not creep fed, weaned, wintered to gain 1.0 to 1.25 pounds per head per day, grazed for 60 days without grain and then put into a feedlot for finishing.

The average daily gains on the wintering ration by Hereford was 1.08 pounds, Charolais 1.32 pounds and crossbred 1.28 pounds revealing 1.6 percent heterosis advantage for the crossbreds.

In Missouri tests average daily gain of straightbred and crossbred steers on grass were Angus .74 pounds, Hereford .64 pounds and Charolais .82 pounds for a .02 pound heterosis advantage. Charolais-Hereford crosses averaged .85 pound for a .12 pound heterosis advantage and Hereford-Angus crosses averaged .69 pound with no heterosis advantage.

In Nebraska tests Gregory et. al., (1968) reported that Hereford, Angus, and Shorthorn crossbred heifers being grown for herd replacement average daily gains showed significant heterosis effects from weaning through 550 day weights in heifers fed for a low rate of gain to calve as three-year-olds. For heifers on a higher energy ration heterosis effects were significant only to 396 days. Gregory stated that these results tended to indicate that heterosis effects are greater under a feeding regime that results in a low rate of gain, and heterosis effects on growth rate decrease with increasing age after one year of age.

In a Montana, test, with inbred lines of Hereford cattle, a 4.3 percent heterosis advantage for post weaning growth was observed when ten years' data was analyzed.

In a Montana trial reported later by Urick et. al., (1968) the same inbred and line crosses of Hereford heifers in 19 out of 20 line cross types showed a positive heterosis advantage of 9.5 percent from weaning to 12 months of age but only 1.1 percent heterosis advantage from 12 to 18 months. Thus percent heterosis advantage decreased from weaning to 18 months of age as was also the case in the previously reported Nebraska

research results.

Crossbreeding experiments were conducted in Florida to evaluate heterosis effects on rate of gain from weaning to feedlot. This trial included a wintering and summer grazing period on 497 heifers and steers. Calves used were classified as to their percent of Brahman blood. Breeding other than Brahman was mainly Shorthorn with some infusion of Angus, Hereford, and Devon. In summary, Peacock et. al., (1966) stated that the one half Brahman calves were superior to calves with more or less Brahman breeding in both wintering and summer grazing trials. Half Brahman calves were followed in gains by over one-half Brahman calves with calves having less than one-half Brahman breeding having the lowest rate of gain. The superior performance of the half Brahman cross calves was thought to be due to a higher level of hybrid vigor. The half Brahman calves were not more efficient in utilizing their feed than the other groups for increased gains but instead consumed a larger amount of feed. The weight gains of the over one-half Brahman calves in comparison to those with over half British breeding was thought to be due to differences in adapting to the Florida climate. This seemed to affect both intake and utilization of feed.

Feedlot gains

Feedlot gains in Nebraska tests followed the same pattern as did preweaning, wintering and pasture gains, when overall averages were adjusted for year, sex and management system. Average daily gains were Hereford 2.18 pounds, Charolais 2.36 pounds and crossbred 2.32 pounds. This gave a heterosis advantage of 2.2 percent. The greatest amount of heterosis was expressed by the crossbred calves which were creep fed and finished

immediately following weaning. In this management group the crossbred

calves were equal to the Charolais straightbred and superior to the

Hereford straightbred calves. Over the entire trial the crossbred

calves exhibited an average of approximately 4 percent heterosis on

increases in gain and final weight.

A two year summary of data in Missouri trials revealed a + .6 pound

heterosis advantage in average daily gain for full fed steers and heifers

fed for 139 and 183 days, respectively. A heterosis advantage of .07 pound

resulted when steers and heifers were fed for 196 and 267 days. In both

of these feeding trials the Angus-Hereford crosses exhibited the most

hybrid vigor in average daily gain with the short feed period heterosis

advantage being slightly over twice as high as was the long feed heterosis

advantage. In general, this trial agreed with the Ohio findings in that

Charolais were in general superior to both the crossbred and the

other straightbred breed averages with heterosis advantage decreasing with

age or length of feeding period.

Nebraska heterosis studies reported by Gregory et. al., (1968) are

in general agreement with those at Ohio and Missouri. Data on Hereford, Angus,

and Shorthorn straightbreds and their recriprocal crosses was analyzed for

a four year period and showed a heterosis advantage for weight of cross-

bred steers at 200, 284, and 268 days and a heterosis advantage in

average daily gain for this same period. The heterosis advantage decreased

with increasing age, when the heterosis advantage for the last one-third

of the feeding period not being large enough to be significant. In

general the heterosis effect decreased with increasing gains while there

were breed effects influencing the rate of gain.

Urick et. al., (1968) reported Montana trials and noted that when

straight line and linecross Hereford bulls were tested for heterosis effect

for rate of gain at the start of the trial which decreased gradually to
-2.2 percent at the last for an overall total of 2.9 percent for 196
days gain.

In Canadian trials with crossbred calves out of Shorthorn dams,
mated to Hereford Angus, Shorthorn, Charolais bulls, Hidiroglou et.al.,
(1966) found that the Charolais-Shorthorn crosses exceeded all other
groups in gain and final weight followed by the Angus-Hereford cross with
the straightbred Shorthorns having the lightest final weights.

Results reported by Damon et. al., (1961) on Louisiana trials agree
with the preceeding findings. Feedlot gains by Angus, Brahma, Brangus,
Hereford, Shorthorn, and Charolais straightbreds and crosses revealed
a highly significant heterosis advantage in favor of crossbreds. There
was large variation in the amount of heterosis exhibited between the
various crosses. The greatest amount of heterosis occurred in crosses
involving parental breeds of widely divergent sources such as the
Brahman-Hereford cross.

Heterosis effect on feedlot gains have varied considerably in
Florida crossbreeding experiments. Most of the trials have revealed no
significant difference between straightbreds and the crossbreds in feedlot
gain. In general, Brahman and Brahman-British crossbreds have been about
equal. One reason for differing results may be environment. Cattle
brought into Florida, especially those of British breeding, require an
adaption period. In fact, this is one of the main reasons for using
Brahman cattle in the south. Crosses with English breeds produces a calf
which is somewhat more heat tolerant to this area.

Chapman (1966) reported on feedlot gains of two year old steers at Florida and found Charbray and Santa Gertrudis breeds superior to the straight and crossbred Brahman, Hereford and Angus. In general, the Charbray and Santa Gertrudis were followed by the crossbreds and then the straightbreds. The Hereford X Brahman cross showed a 12 percent heterosis advantage over the average of the parental breeds in the feedlot. These rankings also held true on pasture gains although not all differences were significant.

FEED EFFICIENCY

Ohio crossbreeding trials with Charolais and Herefords revealed a highly significant difference in TDN required per 100 pounds gain between heifers and steers on feed and between the trials and two systems of management (creep-feeding, feedlot vs. no creep, wintering, pasture, feedlot) however differences between breeds and their crosses were not significant. The Charolais and crossbred calves gained more rapidly than the Hereford calves, but they also consumed more feed. It can be assumed that the Charolais and the crossbred calves were heavier they also required proprotionally more feed for maintanence.

Gregory (1966) reported on heterosis effects on feed efficiency in Nebraska trials. Hereford, Angus, and Shorthorn breeds and their crosses were used. The heterosis effect for feed efficiency was small and generally not significant. As in Ohio trials increased gains in cross-bred calves were due to increased feed consumption.

Feed efficiency studies from Missouri trials reported by Comfort and Lasley (1968) indicated higher heterosis advantages ranged from -.01/

1 pound gain to -1.77 per pound of gain. There was considerable
influence of breeds and length of feeding period upon variation in feed
efficiency. Heterosis effect on feed efficiency was greater for the
longer feeding period.

A summary of south-central states trials by Koger (1966) revealed
that differences in efficiency of feed conversion due to heterosis effects
were too low to be of economic significance. The increased growth rate
of crossbred calves was due to an increased appetite rather than improved
efficiency of feed utilization.

CARCASS TRAITS

Gregory (1966) reported in Nebraska crossbreeding trials, crossbred
steers possessed a highly significant heterosis effect on carcass
weight and net merit (value of boneless, closely trimmed retail cuts-feed
costs from weaning to slaughter). Hereford crosses were superior to the
Angus and Shorthorn crosses. Crossbred carcasses were slightly fatter than
the straightbred carcasses, however, when the differences were adjusted
for carcass weight the difference in fat were negligible. The heterosis
effect on weight at a constant age.

Missouri findings reported by Comfort and Lasley (1968) agreed with
the Nebraska results, with a 3.9 percent crossbred carcass weight heterosis
advantage for the short feeding period and a 2.8 percent heterosis advantage
in carcass weight for the longer feeding period. The crossbred carcasses
were also slightly fatter. Carcass weight heterosis advantage again varied
with breed. Charolais crosses possessed less heterosis advantage than
Hereford-Angus crosses, especially in conjunction with long feeding periods.

Percent fat in crossbred carcasses over the parental breed averages varied from .26 percent for the Charolais-Angus crosses to 1.0 percent for the Angus-Hereford cross.

Ohio test results were similar to Nebraska and Missouri trials. Klosterman et. al., (1968) reported a 3.8 percent heterosis advantage for slaughter weight (total pounds and pounds per day of age) carcass weight, and weight of edible portion per day of age. Percent fat trim was 3.1 percent greater for the crossbred carcass than the straightbred.

Virginia data on carcass characteristics of British cross steers and heifers was reported by Gaines et. at., (1967). Results indicated heterosis advantage for crossbred carcass in traits associated with growth, mainly carcass weight, longissimus dorsi area, and carcass length. Carcass traits not directly related to grwoth rate had little evidence of heterosis.

Canadian tests with Charolais, Angus, Hereford and Shorthorn breeds and their crosses revealed a heterosis advantage in carcass weight (especially Charolais Shorthorn), with no difference between crossbred and straightbred carcasses in dressing percentages, percent boneless meat or percent hindquarter. These results were reported by Hidiroglou et. al. (1964.

Riggs (1966) concluded in Texas crossbreeding tests with 1,000 cattle that the Hereford-Brahman crosses had a significant advantage over the straightbred Herefords in carcass weight (45 pounds) and dressing percent which tended to be 2 to 4 percent higher than the Herefords. Cut-out values between the Hereford and Brahman were very similar. The cross-bred carcass had as high or higher yield of high priced cuts than the

Hereford carcasses. According to Riggs (1966) when crossbreds are produced by mating desirable parents and managed the same way as good-quality European cattle, there appears to be little justification for discrimination against them as slaughter cattle up to 1,000 pounds in weight. This statement may also be made in comparing British crossbreds to straight-breds.

Tests conducted to compare tenderness of meat from Brahman crossbred cattle in Florida was reported by Palmer (1966) who concluded that cattle with 50 percent or more Brahman breeding were less tender than those with 25 percent or less Brahman breeding. There was a considerable variation between individuals in all breed groups.

Carpenter (1963) stated that British breeds of cattle in Florida produced carcasses with a grade of good while Brahman-British crosses produced carcasses with a grade of average. British cattle had slightly more marbling and the carcasses had a slightly younger appearance than the crossbreds. Based on these traits, the Brahman crosses averaged one-third of a grade lower than the British crossbreds.

In general, all cattle crossbreeding experiments reviewed indicated a heterosis effect for carcass weight and for those characteristics directly related to weight (rib-eye, carcass length, etc.) with a slight tendancy in some cases to have a higher percent fat in the crossbred carcass.

CONCLUSIONS

In general, results of the crossbreeding trials are in agreement
with the predictations made by a genetic analysis of crossbreeding.
Traits affected the most by crossbreeding were those traits that are
lowly or moderately heritable. Also crosses between widely divergent
parental sources tended to produce a greater amount of heterosis in the
offspring. The breed effects on heterosis were the primary effects for
variation in heterosis percent throughout the tests that were reviewed.
In general, the effects of heterosis were greater in young calves and
decreased with increasing age. Variation in heterosis expressed between
different breed crosses and among individual animals within the same test
was large in almost all tests. This variation was in part due to
environmental causes such as climate, year effects, management systems,
sex, and maternal affects as well as random variation. Some of these
factors were adjusted for on a within test basis in order to get a more
accurate estimate of genetic causes of variation. In the various
tests, these factors tended to cause such a large variation that
establishment of an average estimate of heterosis for specific production
traits was impossible.

Some general effects of heterosis on the various beef cattle
production traits can be summarized from the literature.

REPRODUCTIVE EFFICIENCY

As for other species of farm animals, reproductive efficiency was one
of the main traits affected by crossbreeding in beef cattle.

The trait is lowly heritable and involves both cow fertility and livability of calves.

In British breed crosses the heterosis effect exhibited as percent calf crop at weaning, was at approximately the 3.0 percent level. The biggest advantage of crossbreeding to improve reproductive efficiency came through increased calving percentages exhibited by crossbred cows. These advantages averaged about 8-10 percent over those of straightbred dams with crossbred calves.

Results of Brahman-British breed crossbreeding trials were more variable exhibiting from 1 to 6 percent heterosis in favor of the crossbred cows calving percentages. The main factor affecting these percentages seemed to be the lactation status of the Brahman and crossbred cows. These cows exhibited approximately a 10 percent decrease in calving percents due to a failure to ovulate and exhibit estrus while nursing a calf. The crossbred cows were intermediate in calving percents and did exhibit a six percent advantage over the average of the calving percents of the straightbred Brahman and British dams in one test. Florida researchers felt that calving percentages in their area could be greatly improved by a systematic rotational crossbreeding program and vigorous culling of open cows.

LONGIVITY

Only one test of those reviewed referred to longivity or lifetime production of the crossbred beef cow. In a long term Canadian crossbreeding test involving the Brahman, Hereford, Angus, and Shorthorn breeds

the crossbred cows were found to be superior in longivity and lifetime
production to straightbred cows on an average. No percent superiority
was given in the results.

BIRTH WEIGHT

The ideal birth weight of calves would be one which was as heavy
as possible without causing an excess of calving problems since there does
seem to be a correlation in some tests between birth weight and rate of
gain.

Heterosis for birth weight in most trials reviewed was at
approximately the three percent level. There was a good deal of variation,
depending on the breeds involved in the cross. Generally Charolais
straightbreds and crossbred calves were the heaviest at birth. Only one
test (Ohio) noted any calving difficulties which might be due to calves which
were too large. In this test 33 percent of the Charolais sire and Hereford
dam calves required assistance at parturition. There were few problems
except for first calf two year old heifers. This is a point that should
be considered by the cattleman who is setting up a crossbreeding program.
A careful analysis of choice of breeds, and size of cows, especially
heifers, should be made before setting up a crossbreeding program.

In trials involving Brahman cattle in the southern region, British
breed-Brahman calves were slightly lighter than straightbred calves, however,
at weaning the same calves averaged 10 to 70 pounds heavier than the
straightbred calves.

PREWEANING GROWTH RATE

Preweaning rate of growth, along with reproductive performance, is most influenced by crossbreeding. The weaning weight of a calf is due to the mothering ability of the dam and the genetic potential for growth of the calf.

Mothering ability of dam

The effect of mothering ability of the dam was best demonstrated in crosses involving the Brahman and Brahman crossbred cow. Crossbred calves with British dams had an average of five percent heterosis in weaning weight over the straightbred calves while crossbred calves with Brahman dams exhibited a 12-15 percent advantage over the straightbred calves. In general crossbred calves with crossbred Brahman dams were equal to or superior to crossbred calves with straightbred Brahman dams who in turn were superior to crossbred calves from British dams. In one trial involving the British breeds of cattle, crossbred dams were superior in milk production by .47 to .84 pound of milk per 12 hour period.

Growth abillity of calves

Heterosis influence on weaning weight of crossbred calves out of straight bred dams averaged approximately five percent but varied from 1.2 percent to 13 percent in the trials reviewed for the report. The actual amount of heterosis varied, depending on the breeds involved in the cross. Usually, Charolais straightbreds were equal or superior to crossbred calves in weaning weight with heterosis exhibited by Charolais-British breed crosses being equal to crosses between British breeds. Crossbred calves from British breeds almost always were superior to the parental breeds.

British-Brahman crossbred calves with Brahman dams averaged approximately 12-15 percent heterosis for average daily gain although part of this was due to the maternal ability of the Brahman and Brahman crossbred dams.

The largest advantage of crossbreeding was revealed when pounds of calf produced per cow was investigated. Nebraska trials indicated a 17 percent advantage in pounds of calf produced percow when crossbred cows were used in a three breed crossbreeding program. This did not acknowledge the 3 percent advantage percent in calf crop weaned and 4.5 percent advantage in weaning weights of crossbred calves from straightbred dams. Canadian findings supported these with 25 percent advantage over straightbred Herefords in Kilograms calf weaned per crossbred cow in a backcross and a 64 to 87 percent advantage in a three breed cross. This test used Brahman-Hereford cross cows and did not list advantage as heterosis but as advantage over straightbred Herefords.

WEANING CONFORMATION SCORES

Heterosis effects on weaning conformation scores in general were low or no effect was noted. Heterosis percent varied from 0 to 2.7 percent. The advantages were usually less than one-third of a grade in British breed crosses. Brahman-British crosses scores somewhat higher with calves from half bred Brahman-British cows backcrossed to British bulls producing calves which graded one-third of a grade higher than the calves from crossbred cows with more or less Brahman breeding

POST WEANING GAIN

Low energy rations

Percent heterosis for post weaning growth varied a good deal, depending upon the breeds involved and the length of time over which the heterosis advantage was measured. One point on which all trials agreed was that heterosis decreases rapidly as the animal matures whether on a low or high energy ration. In general, heterosis advantages averaged 1 to 4 percent level. These trials on low energy rations mainly involved the growing out of breeding cattle and heterosis advantage of this growth rate usually was significant up to an age of one to one and one-half years. In trials involving Brahman crossbred calves, the growth rate of the first cross was superior to all other crosses and was attributed to a greater degree of heterozygosity as well as adaptibility to the gulf coast climate.

FEEDLOT GAINS

Feedlot gains followed much the same pattern as did gains on lower energy rations with the exception of the Brahman crossbreds in the southern states. Overall average expression of heterosis in feedlot gains was about four percent level. The Charolais and Charolais crossbreds usually had the highest rate of gain followed by the British breed crosses which were superior to straightbred averages. As with low energy rations, heterosis percentages decreased rapidly with increasing age. When Brahman crossbred cattle were tested outside of the southern regions, these crosses with British breeds often produced rates of gain which were superior to other British-British crosses. This was possibly due to the genetic diversity of the parental breeds causing increases in heterozygosity in the off-spring.

In southern trials, involving Brahman-British crosses, little or no heterosis was exhibited by the crossbred feeder cattle. This was probably due in part ot environmental factors. Breeds such as the Santa Gertudis and Charbray cattle produced the fastest gains followed by British-Brahman crosses which were equal to or slightly superior to the straightbred rate of gains.

FEED EFFICIENCY

Heterozygosity for feed efficiency was very low or nonexistant in most trials reviewed for this report. Although crossbred calves gained faster than did straightbred calves, this was accompanied by an increased feed intake, in almost all cases. Heterozygosity exhibited for feed efficiency was so low as to be insignificant on a practical basis. This was true of all breed crosses and management systems although feed efficiency was affected by breed, sex, and management systems.

CARCASS TRAITS

All tests reviewed agreed that the main heterosis effect on carcass traits was that of increased carcass weight on an age constant basis.

Crossbred carcasses exhibited about a two-four percent heterosis advantage for weight. The crossbred carcass tended to be somewhat fatter than the straightbred carcasses but when put on an equal weight basis the amount of extra fat was negligible. No consistant significant differences in carcass composition were noted when the crossbred and straightbred carcasses were put on a percentage basis.

In Brahman-British breed crosses the animal with 50 percent or more

Brahman breeding produced meat that was slightly less tender, appeared somewhat older, and graded about one-third of a grade lower than did animals with 25 percent or less Brahman breeding.

CROSSBREEDING PROGRAMS

As can be seen from these results crossbreeding is not a quick, easy method for improving calving and weaning percentages, conformation faults and weight gains. When crossbred cattle are mated indiscriminately the production traits will usually decrease instead of increase. Successful initiation of a crossbreeding program requires a careful analysis of the straightbred cattle to be used as a basis for the crossbred herd, careful selection of bulls that will produce superior offspring, and a carefully set up crossbreeding program with facilities for proper handling of the various breeding groups within a herd.

The cattleman should also be willing to "live with" the problems that accompany a crossbred herd in return for the increased growth and vigor of his calves.

The steps that a commercial cattleman should go through before starting a commercial crossbred herd should include the following considerations:

(1) A detailed analysis of his present straightbred herd should be made, specifically that of calving percentages, and weaning weights. Since these are the two traits that are most affected by crossbreeding. If his present herd has high averages in comparison to other herds in these traits a crossbreeding program will probably not be advantagous to him.

(2) The cattleman should decide whether or not he can accept the lack of uniformity in both color and type which goes along with a cross-breeding program, especially those involving a three or more breed cross.

(3) The market preference for crossbred calves in his area should also be analyzed. If crossbred calves sell much below straightbred calves the producer could find himself in the position of selling more pounds of calf for less money. In general after a breeder has built up a reputation for producing quality calves this price discrimination should not exist.
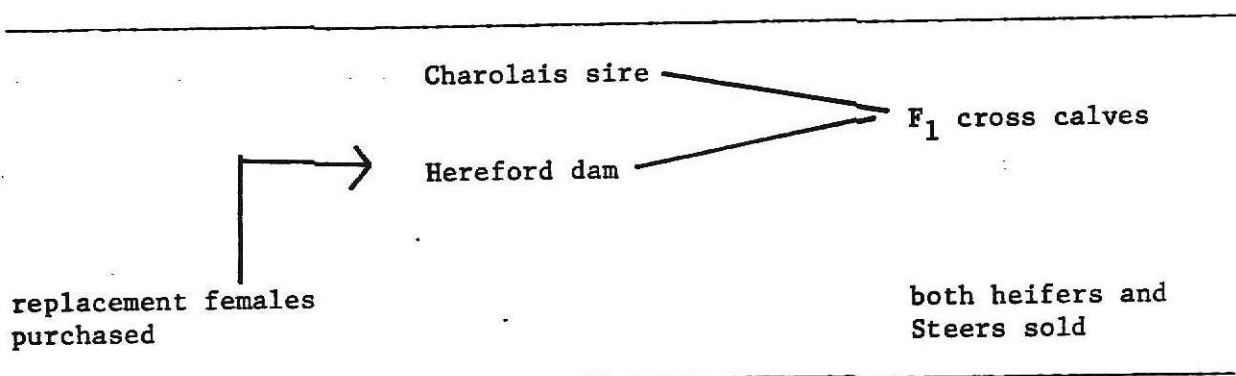
(4) The cattleman should choose a crossbreeding program and have the extra facilities required to make it work before he starts his cross-breeding program.

There are three programs that are usually used in a crossbred operation.

The first of these is mating straightbred dams of one breed to purebred bulls of another breed to produce F_1 crossbred calves for market. An example of this would be as follows.

TABLE VIII

TWO BREED CROSSBREEDING PROGRAM

Charolais sire		
Hereford dam	→	F_1 cross calves
replacement females purchased		both heifers and Steers sold

The biggest disadvantage of this program is the purchasing of all replacement females which offsets its advantage of simplicity. Also, the F_1 cross heifers are not used for breeding purposes, thus a good deal of the heterosis advantage is lost.

The second program that can be used involves a two breed cross and is known as crisscrossing. This program requires two herds because of the overlapping of generations. An example of this program follows:

TABLE IX

TWO BREED RECRIPROCAL CROSS

	Herd 1 Hereford sire	Herd 2 Shorthorn sire
First 2 years	Shorthorn females	-------
3 years +	Shorthorn and increasing numbers of crossbred heifers in later years for back-crossing.	F_1 Hereford-Shorthorn female and increasing numbers of crossbred heifers.
Source of replacement females	Herd 2	Herd 1

After initiated herd 1 and 2 should be equal in size to maintain equal selection pressure

The advantage of this system is the use of crossbred females in a backcross program which produce superior offspring in comparison to straightbred females. The main disadvantage is the added facilities and work required to keep two breeding groups separate.

A three breed cross, which has produced the maximum sustained amount of heterosis generation after generation, is similar to the two breed or crisscross program. This system does, however, involve more labor and facilities since the herd must be handled in three breeding groups. An example of the three breed rotational cross would be as follows:

TABLE X

THREE BREED RECRIPROCAL CROSSBREEDING

Herd 1	Herd 2	Herd 3
Hereford Bulls	Angus Bulls	Shorthorn Bulls
X	X	X
Shorthorn cows and replacement heifers from herd 3 after 7 years.	Hereford-Shorthorn heifers after 3 years, replacements from herd 1	Hereford-Shorthorn Angus crossbred cows 5 years after program start, replacements from herd 2.

These herds, as in the two breed cross, should be equal in size to maintain equal selection pressure. Breeding of these herds progency would be: herd 1--57 percent Hereford, 29 percent Shorthorn, 14 percent Angus; herd 2--57 percent Angus, 29 percent Hereford, 14 percent Shorthorn;

herd 3--57 percent Shorthorn, 29 percent Angus, and 14 percent Hereford.

Another program related to those already mentioned, but lacking in efficiency in comparison, is periodic changes in breed of bulls. In this program only one breeding herd of cows is maintained and breeds of bulls are changed periodically.

When replacement heifers calve as three year olds and cows are culled at eleven years of age the following program could be set up:

Two breed rotation-	change breed of bulls every 6 years.
-	28% incidence of straightbred matings (15% cull).
Three breed rotation	- change breed of bulls every 4 years.
-	10-15% incidence of straight-bred maintings.
Four breed rotation	- change breed of bulls every 3 years.
-	0% incidence of straight-bred matings.

This program is flexible according to the length of time cows are kept in the breeding herd, the number of breeds in the cross, and the age at which heifers first calve. Koger (1966) states that a four breed cycle set up according to this plan should be equal genetically to a four breed conventional rotation scheme along with the advantage of having only one breeding herd and one breed of bulls on the ranch at any one time. The big disadvantage, especially in tow and three breed crosses is the mixed breeding of the breeding herd which in turn affects heterosis.

(5) The combining ability of breeds of cattle is also an important factor that should be taken into consideration. Matings should always be made that will increase the herd average or there will be no advantage to crossbreeding. Bulls of any breed chosen should be superior to the cow herd average in order to produce the maximum amount of heterosis.

After all of these factors are taken into consideration the commercial cattleman should have a good idea of the advantages and disadvantages of a crossbreeding program for his particular situation. As has already been stated, crossbreeding is not an easy cure all for all situations, but is a breeding method which will prove advantageous in certain situations if good planning and management accompany it.

ACKNOWLEDGMENTS

BIBLIOGRAPHY

Brinks, J.S., J. J. Urick, O.F. Pahnish, B.W. Knapp, T.J. Riley, "Heterosis in Preweaning and Weaning Traits Among Lines of Hereford Cattle," Journal of Animal Science, 26:278, 1967.

Cundiff, L.V., and others, "Hybrid Vigor in Beef Cattle," 1968 Nebraska Beef Cattle Report, (University of Nebraska Bulletin (EC 68 - 128).

Cundiff, L.V., and Keith E. Gregory, "Improvement of Beef Cattle Through Breeding Methods," Summary of Results From Regional Project NC-1 North Central Regional Publication 120, (Nebraska: Nebraska Agriculture Experiment Station, 1968).

Cunha, T.J., M. Koger, and A.C. Warnick, Crossbreeding in Beef Cattle, Gainsville: University of Florida Press, 1963.

Damon, R.A.Jr, W.R. Harvey, C.B. Singletary, S.E. McCraine, and R.M. Crown, "Genetic Analysis of Crossbreeding in Beef Cattle", Journal of Animal Science 20:849., 1961.

Flower, A.E., J.S. Brinks, J.J. Urick, and F.S. Wilson, "A Comparison of Inbred Lines and Linecrosses for Performance Traits", Journal of Animal Science 22:914, 1963.

Gaines, J.A., W.H. McClure, D.W. Yogt, K.C. Carter, C.M. Kincaid, "Heterosis From Crosses Among British Breeds of Beef Cattle: Fertility and Calf Performance to Weaning", Journal of Animal Science 25:5, 1966.

Gaines, J.A., G.V. Richardson, W.H.McClure, D. W. Vogt, and R.C. Carter, "Heterosis From Crosses Among British Breeds of Beef Cattle: Carcass Characteristics", Journal of Animal Science, 26:1217, 1967.

Gregory, K.E., L.A. Swiger, R.M. Koch, L.J. Sumption, J.E. Dngalls, W.W. Rowden, and J.A. Rothlisburger, "Heterosis Effects on Growth Rate of Beef Heifers, "Journal of Aniaml Science, 25:290, 1966.

Gregory, K.E., L.A. Swiger, L.J. Sumption, R.M. Koch, J. Edngalls, W.W. Rowden and J.A. Rothlisberger, "Heterosis Effects on Growth Rate of Beef Heifers", Journal of Animal Science, 25:290, 1966.

Gregory, K.E., L.A.Swiger, L.J. Sumption, R.M. Koch, J.E. Dangalls, W.W. Rowden, and J.A. Rothlisberger, "Heterosis Effects on Carcass Traits of Beef Steers", Journal of Animal Science, 25:311, 1966.

Hidiroglou, M., L.A. Charette, and J.S. Patterson. "A Comparison of Growth and Carcass Characteristics of Purebred Shorthorn, and Crossbred Beef Steers", Canadian Journal of Animal Science, 44:249, 1964.

Hidiroglou, M., and others, "Comparative Growth Rates of Shorthorn and Crossbred Beef Calves From Birth to One Year of Age," Canadian Journal of Animal Science, 46:217, 1966.

Holt, Leroy H., "Crossbreeding in Beef Cattle" Journal of Animal Science, 14:1185, 1955.

Klosterman, Earle W., V.R. Cahill, and C.F. Parker, A Comparison of the Hereford and Charolais Breeds and Their Crosses Under Two Systems of Management, Research Bulletin 1011, (Ohio: Ohio Agricultural Research and Development Center. 1968).

Lasley, John F. Genetics of Livestock Improvement. Englewood Cliffs: Prentice-Hall, Inc., 1963.

Lawson, J. E., and H.F. Peters, "The Birth and Weaning Weights of Highland and Hereford Cattle and Their Recriprocal Crosses," Canadian Journal of Animal Science, 44:174, 1964.

Missouri Heterosis Experiment, Cooperative Project in the NC-1 Beef Cattle Breeding Project (Missouri: North Missouri Center, Spickard, September, 1968.)

Peters, H.F., and S.B. Slen, "Brahman-British Beef Cattle Crosses in Canada 1. Weaned Calf Production Under Range Conditions", Canadian Journal of Animal Science, 47:145, 1967.

Rice, Victor R., Andrews, Frederick, Everett J. Warwick, James E. Legates "Breeding and Improvement of Farm Animals. New York: McGraw Hill Book Company, 1957.

Schilling, E. Prentiss, and Noah C. England, "Some Factors Affecting Reporduction in Beef Cattle", Journal of Animal Science, 27:1363, 1968.

Stonaker, H.H., "Observations of Reproduction, Growth, Feed Utilization, and Grades of Inbred and Outbred Hereford Cattle", Journal of Animal Science, 13:963, 1954.

Temple, R.S., and D. D. Miller, "A Comparison of Calving Percentages and Preweaning Performance of Various Breeds of Beef Cattle in a Crossbreeding Program", Journal of Animal Science, 20:392, 1961.

Turner, J.W., B.R. Farthing, and George L. Robertson, "Heterosis in Reproductive Performance of Beef Cattle", Journal of Animal Science, 27:336, 1961.

Urick, J.J., J.S. Brinks, O.F. Pahnish, B.W. Knapp, and T.M. Riley "Heterosis in Postweaning Traits Among Lines of Hereford Cattle", Journal of Animal Science, 27:323, 1968.

Wiltbank, J.N., K.E. Gregory, L.A. Swiger, J.E. Dangalls, J.A. Rothlisberger, and R.M. Koch, "Effects of Heterosis on Age and Weight at Puberty In Beef Heifers," _Journal of Animal Science_, 25:744, 1966.

CROSSBREEDING IN BEEF CATTLE

by

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AN ABSTRACT OF A MASTER'S REPORT

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This report is a summary of some of the beef cattle crossbreeding research that has been conducted within the United States and Canada, with particular emphasis on the research done by Regional Project NC-1, "Improvement of Beef Cattle Through Breeding Methods." The main objective of this research has been to learn the effects of heterosis on the economically important beef cattle production traits.

Heterosis was evaluated for reproductive efficiency, longivity, birth weight, pre and post weaning gain, feed efficiency, weaning conformation score, and carcass traits.

Breeds involved in these trials were predominantly Hereford, Angus, Shorthorn, Charolais, and Brahman.

Percent heterosis for each trait varied considerably between the various tests. This variation was due to factors such as breed, climate, year, age, management program, and other various environmental factors.

Taking these factors into consideration, the following conclusions appear justified:

1. Crossbred cow breeding efficiency and pounds of calf produced per crossbred cow were the two traits which showed the greatest heterosis effect. Heterosis for reproductive efficiency for the crossbred cow averaged about eight to ten percent. Heterosis for pounds of calf produced per cow was seventeed percent or higher.

2. With the exception of breeding efficiency and pounds of calf produced per cow, all of the major production traits exhibited a five percent or lower heterosis effect.

3. British-Brahman breed crosses, heterosis percents varied considerably more than did British-British crosses.

4. Crossbreeding would be the most successful for raising a herds calf crop percentage and weaning weights especially when crossbred cows are used.

5. The maximum amount of heterosis is produced by, and can be maintained through a three or more breed rotational crossbreeding program.

6. Crossbreeding requires increased management and facilities.

7. Crossbreeding must be done in a systematic manner for maximum heterosis advantage.