SHOULD YOU CONSIDER CROSSBREEDING?

Bennet Cassell
Extension Dairy Scientist, Genetics and Management
Virginia Tech, Blacksburg

In the years just prior to and following World War II, American agriculture explored crossbreeding extensively for just about every species of plant and animal of economic importance. Some of you may remember, or at least remember your fathers talking about the wonders of hybrid (crossbred) corn. The thinking was that something that worked so well for corn was bound to have some benefits for other species. Dairy was no exception – several long-term cross breeding projects were conducted at experiment stations and universities around the country.

Results of those projects were mixed. Crossbred cattle were superior to the average of the parental breeds (positive heterosis) for many traits. However, there was no one cross that consistently produced more milk in a single lactation than the Holstein cow. That one fact, plus a widespread purebred preference by managers of many of the experimental herds produced the conclusion that within breed selection was preferable. So, a purebred system improved by within breed selection is what the dairy industry has practiced for the ensuing 30 years.

Today, crossbreeding is back on the table for discussion for the following reasons:

1. The pure breeds are increasingly inbred, and there are few options available to alter this course of events for dairy populations under selection.

2. Holstein cows have dystocia problems.

3. Multiple component milk pricing systems are widespread in the United States. Direct payments for protein as well as fat encourage some owners of Holstein herds to consider crosses to higher component breeds.

4. Reproductive efficiency, health, and survival have become more important economically as genetic progress for milk production has made cows much more productive than they were 30 years ago.

5. Replacement heifers are suddenly in short supply. Crossbred calves may (probably will) survive better, grow faster, breed sooner and more reliably, and calve out more successfully than purebreds.

Modern confinement systems, better nutritional management practices, increased yields, more demands on the physiological systems of the dairy cow, and the importance of keeping cows healthy and producing to maintain cash flow also have contributed to interest in crossbreeding. The crossbreeding trials immediately after WWII were conducted in a search for higher producing dairy cows. While some researchers were interested in health, survival, reproductive performance, most producers wanted cows that gave more milk. Today almost every cow in the various purebred populations has the genetic ability to produce at high levels for at least 305 days. Dairy managers can afford to turn their attention to other traits that contribute to lifetime economic merit.

Crossbreeding is a Mating System

Most dairy producers think of their breeding program as a policy that is implemented one cow at a time. They may (hopefully, do) choose their semen inventory with herd requirements in mind, but the matings happen to individual cows. Crossbreeding really needs to be thought of as a system of producing replacements. The genetic makeup of the dam and the breed of the sire will change from generation to generation in a crossbreeding system. The success of crossbreeding will be affected by how well planned that system is.

Following is a section about the genetic principals upon which crossbreeding is based. This material has appeared in other proceedings papers I have written on this topic, because the principals are important information to help producers plan effective crossbreeding systems. As you read what follows, keep in mind that there is much that we have to learn about breed resources and the relative merits of different crosses. There are some concepts, however, that you can pretty well take to the bank.

1. **It is easier to start a crossbreeding program than it is to change your mind** and revert to a pure breed system.

2. **The first cross will likely be one of the very best you ever make**. It will have maximum heterosis, and should involved your favorite breeds – the one you have now and the one you would go to if you didn't have the one you have now. Early success may lull a manager into complacency. Future success with crossbreeding will require good planning and good records.

3. **Within breed selection, using progeny tested AI bulls, will be an important component of a well-planned crossbreeding program.** Breeds that don't have good progeny testing programs will be limited in how effectively they can contribute to a crossbreeding program.

Basic Principals of Crossbreeding

Selection and crossbreeding operate differently. Selection increases the frequency of desirable genes in future generations. Changes in gene frequency are permanent changes, and transfer from one generation to another. The idea with crossbreeding is to desirable gene *combinations* from the sample half of genes transmitted to offspring from sire and dam. The benefits of crossbreeding apply only to the animal that is produced. Good gene combinations break down when crossbreds produce offspring, and sustainable crossbreeding programs must include methods to regenerate desirable gene combinations in each new generation. It may be useful to think of crossbreeding as the opposite of inbreeding. The following is an abbreviated summary of how crossbreeding and inbreeding are related.

Dairy cows, people, and other animals are *diploid* organisms. Genes that control the bodily functions of cows operate in pairs, with one gene inherited from each parent. When parents are related, some of those genes are copies of the same gene in an ancestor(s) that appears in both pedigrees. Mating of related individuals is called *inbreeding*, and one of the consequences of inbreeding is *inbreeding depression.* It results from pairs of undesirable recessive genes that retard health and fitness traits, hamper reproduction, and in some cases are lethal. When parents have divergent genetic backgrounds, (different breeds) those undesirable recessive gene *combinations* never form in offspring. One advantage of crossbreeding, *heterosis*, is really the absence of inbreeding depression. The breeds used need to be genetically different for heterosis to occur. Crosse of red or black and white Holsteins, for instance, won't produce much heterosis at all.

The examples that follow use Punnett Squares, a handy tool from animal breeding classes to show how genes from parents combine in a new generation. Single-letter entries at the row or column headings show individual genes transferred by sperm or egg cells from parent to offspring. The letter **H** identifies Holstein genes, **J** indicates Jersey genes, and **S** indicates Brown Swiss genes. Other breeds could be used to create the crosses, so don't attribute undue importance to the breeds used in the examples. Pairs of letters, in bold type, show the *gene combinations* carried by offspring of a mating. If the table contains only one combination, then all gene pairs produced by the cross will consist of genes with the breed origins specified. If a table contains two cells with pairs of letters, then half the gene pairs will be of one type and half will be of the other type. If four cells contain pairs of letters, then 25% of gene pairs produced by the mating specified will be of each type. When the breed origins of the two genes are different (i.e., the letters are different) then some heterosis can be expected from gene pairs with the indicated breed backgrounds. If both genes in a pair show the same breed of origin, then performance generated by that pair of genes should be comparable to a purebred animal.

A cross of two pure breeds to produce an F1:

- This example creates an F1 using Jersey bulls (the row) on Holstein cows (the column). Every pair of genes in the offspring consists of one gene of Holstein origin and one gene of Jersey origin. Such a cross generates 100% of the heterosis possible from the two breeds involved. The heterosis produced is specific for the two breeds involved and is NOT of equal size for all traits. Heterosis can be large or small, and positive or negative, depending on the trait and breeds involved.

Individual genes contributed by sire or dam	100% H
100% J	**100% JH**

Use a crossbred bull on a purebred cow:

- There are voices in the dairy breeding industry advocating the use of crossbred bulls. The mating below is between crossbred Swiss-Holstein sire and a Jersey cow. It generates 100% of the heterosis possible from the breeds involved. Producers who use crossbred bulls lose a lot of opportunity for within breed selection, as no progeny test information would be available. If we progeny test such bulls in the future, this option may become more useful. This mating also allows for *paternal* heterosis, as the sire is crossbred. Whether paternal heterosis is useful in an AI program is questionable. If natural service is used, crossbred bulls may be more sexually successful than purebred bulls. Crossbred boars are used in swine breeding programs because of sexual activity and for other purposes.

Individual genes contributed by sire or dam	100% J
50% S	**50% SJ**
50% H	**50% HJ**

Inter-se **(among themselves) matings of F1's:**

- One crossbreeding plan is to mate Holstein-Jersey F1 cows to a Holstein-Jersey F1 bull. The offspring of such a mating are called F2's. One half of the gene combinations (those with JJ and HH designation) include genes with the same breed of origin, meaning no heterosis at those gene locations. Mating F1 females to F1 males of the same cross maintains 50% of the heterosis that was in the F1. If this scheme is continued to make F3's, F4's, and so forth, heterosis will remain at 50% of heterosis in the F1. The loss of heterosis aside, the bulls from such a plan will not likely be progeny tested. However, this cross can express both paternal and maternal heterosis. I don't expect inter-se matings to be a popular or widely adopted plan for dairy producers, at least in the near future, since selection among males on the basis of progeny performance will not be possible.

Individual genes contributed by sire or dam	50% H	50% J
50% H	**25% HH**	**25% HJ**
50% J	**25% JH**	**25% JJ**

Two-breed rotation systems:

- The first step in a two-breed rotation, of course, is to produce the F1. Frequently, F1's are mated to the breed other than the sire breed that created the F1, but I know of no genetic reason why the dam breed that created the F1 could not be used instead. The offspring of the F1 shown in the next Punnett Square would be designated as an HJH if it was understood that only purebred sires were used or H(JH) otherwise. A backcross of F1's to one of the original breeds maintains 50% of the heterosis that was in the F1 generation. The particular crossbred animal carries 75% Holstein genes and 25% Jersey genes, and would express breed characteristics accordingly. If successive backcrosses to Holsteins were continued, the system would change from a two-breed rotation to a "grading up" program to pure Holsteins. Percent Holstein genes would be 87.5% in the third generation, 93.75% in the fourth generation, and so forth.

Individual genes contributed by sire or dam	50% J	50% H
100% H	**50% HJ**	**50% HH**

The next step in a two-breed rotation is to mate the first backcross to a Jersey sire. This cross, shown in the next diagram, breaks down all the homozygous HH combinations, creates 25% JJ combinations, and achieves 75% of the hybrid vigor in the F1.

Individual genes contributed by sire or dam	75% H	25% J
100% J	**75% JH**	**25% JJ**

The cross also contains 62.5% Jersey genes and 37.5% Holstein genes. After several more rotations, breed composition of the cross will stabilize. The breed of the sire will always contribute two thirds of the genes, while the other breed will contribute the balance. The system will retain 67% of the heterosis in the F1. The two-breed rotation will be the choice of breeders who feel that Holsteins and Jerseys are the best breeds for their operations or are reluctant to incorporate a third breed for some reason. One of the drawbacks to the two-breed rotation is the swing in percentage of genes from one breed from generation to generation. Some producers will prefer the crosses with 67% Holstein genes, and never be very happy with the crosses that are 67% Jersey and vice versa. One crossbreed system that avoids such swings is the inter-se mating system, which really creates a synthetic breed from two or more original breeds. Another way to keep the breed composition of the crosses constant would be to use only certain F1's, offspring of a string of purebred cows maintained in the herd, or purchased from an outside source.

Some system of identification would be necessary to identify the breed of sire for each generation in a two-breed rotation of Holsteins and Jerseys. Color patterns in that particular cross crosses won't consistently reveal whether the animal was sired by a Holstein or Jersey bull. Some other breed combinations may mark each generation sufficiently so that breed of sire is clear. The semen inventory in a two-breed rotation would include bulls from two breeds at all times, which does add some complexity to maintaining the program.

A three-breed rotation system:

- Another crossbreeding system is the three-breed rotation. The diagram below shows the mating of a Holstein-Jersey cross female to a Brown Swiss bull. In this cross, every pair of genes inherited by calves produced from the cross has a different breed origin. The offspring of this generation have 100% of the heterosis possible from the breeds involved because every gene pair has one gene from one breed and the other gene from a different breed.

Individual genes contributed by sire or dam	50% H	50% J
100% S	**50% HS**	**50% SJ**

As is true with all rotational systems, breed composition of each generation in a three-breed rotation differs from the previous generation. The breed of the sire will account for 57% of all genes at equilibrium. The breed of the sire of the cow will contribute 29% of all genes, and the remaining 14% of genes will come from the third breed. A three-breed rotation will maintain more heterosis than a rotation of two breeds (86% of heterosis in the F1), but the breeder has to be comfortable with the merits of the third breed and willing to accept the complexity of a three-breed system. Some producers may prefer one breed composition to another, and always be at least a little disappointed with the two-thirds of the herd that don't have the optimum combination. A good identification system would be needed to maintain the rotation of breed of sire correctly, and the semen inventory for the farm would always include all three breeds.

Planning a Successful Crossbreeding System

Breeders have many choices in a crossbreeding design. Most of the important decisions will be based on herd specific conditions and owner preferences.

1. Crossbreeding doesn't have to be used on the entire herd. In fact, a producer who really likes a particular two-breed cross, perhaps Jersey or Brown Swiss sired calves out of Holstein dams, may find it beneficial to maintain pure Holsteins to serve as dams of that specific cross.

2. Considering the lack of recent research results with crossbred cows, it seems appropriate for a dairy producer to gain some experience with crossbreds and compare them to purebred "controls" in his own herd before committing to a major crossbred effort.

3. Breeders can choose two-breed or three breed rotational systems if they want to go to an entirely crossbred herd *and* produce their own replacements.

4. Breeders may prefer a certain kind of F1 crossbred cow – to emphasize the variety of possibilities, let that F1 be a Normande sired calf out of a Holstein dam. They may choose to purchase those specific F1's from a Holstein breeder who breeds some Holstein cows specifically for the crossbred market.

5. A producer who buys crossbred replacements needs to consider how best to use the calves born on the farm to those F1 dams. There may be a market for females from a three-breed rotation, or terminal cross beef sires may be used on mature cows with the beef or veal market in mind.

Whatever route a dairy producer chooses to take, they need to take advantage of three important elements of successful crossbreeding programs. Those elements are:

- **Breed complementation**
- **Within breed selection**
- **Heterosis**

<u>Breed complementation</u> refers to the strengths and weaknesses of a breed. Breeds can be combined to take advantage of those strengths. The classis example is to use the high milk volume of Holsteins and high milk component percentages of a Jersey to crease a crossbred with high volume of components.

<u>Within breed selection</u> has been the powerhouse behind all the genetic progress that has been made in dairy cattle over the past 30 years. It will remain an important force even if crossbreeding is widely practiced. The bottom line for this idea is that producers practicing crossbreeding should not use just any Holstein bull – or Jersey or Swiss or Montbeliarde or Norwegian Red – they should use a really good one.

Heterosis is the extra "kick" in performance that a crossbred gets above the average of the breeds of the parents. It may be most useful to think of heterosis as the opposite of inbreeding depression. Parents from breeds that are genetically different cannot be related, and their offspring will not inherit the same lethal or sub-lethal genes from both parents at any gene location. That means no genetic defects will be expressed that might be expressed if the same parent was mated to another animal from the same breed, especially a closely related animal. Keep in mind that the "bad" genes aren't removed by crossbreeding, but they are hidden as heterozygotes behind dominant "good" genes.

If you mated two crossbred animals that were closely related, like full brother-sister, some of those undesirable gene hidden behind dominant and desirable genes in the parents would appear in the F2 as homozygotes. You would have produced inbreeding depression in crossbred animals! On the other hand, if you mate two highly inbred individuals that are unrelated to each other, the offspring will NOT be inbred. The individual would not have the undesirable gene combinations of the parents, because each parent gives the offspring one gene from the pair. Since the parents are unrelated, the gene they pass on is unlike the gene their mate passes on, and the offspring has heterozygous gene combinations at the gene locations where the parents were homozygous. Heterosis would result from matings of inbred but unrelated parents.

Breed Resources

Most US dairy producers will be milking Holsteins, and most of those same producers will think of Jerseys or Brown Swiss as the logical cross on those Holstein cows. Think of Holsteins, Jerseys, and Brown Swiss as breed resources. Each breed has its own strengths that it can contribute to a cross. Each breed has some weaknesses that may be improved in a cross from breed complementation or by heterosis. Each of these three breeds has made substantial genetic progress in the past. Proven AI bulls are readily available in both breeds. The US bull studs keep proven Brown Swiss bulls around primarily because of demand in the international market. There are only about 16,000 Brown Swiss cows in the US. Not that you would want to, but one Brown Swiss bull in AI could easily breed the lot!

There are other populations of dairy cattle around the world that have also benefited from organized genetic improvement programs. At least four of these breeds could be useful in crossbreeding programs in this country, and a few more years' experience may add a couple of more breeds to that list. The four that come to mind are the **Normande** and **Montbeliarde** breeds from France, and the **Swedish Red** and **Norwegian Red** breeds from those two Nordic countries. Table 1 shows the population sizes and approximate production levels for the US and French breeds. Production levels for the French breeds are difficult to determine for a number of reasons. Production information for the French breeds in Table 1 were estimated by Dr. Les Hansen, dairy cattle breeder at the University of Minnesota, after a recent trip to France to look at Normande cattle. I was unable to locate similar information on the two Nordic breeds, which are, by the way, NOT some strain of red Holsteins. They actually have very little Holstein blood in their pedigrees.

Table 1. Tested population sizes and production of potential breed resources for crossbreeding programs.

Breed	Cows on production test in 2000	Approximate 305 d ME milk	Approximate 305 d ME fat	Approximate 305 d ME protein
Holstein	3,900,000	23,300	845	696
Jersey	158,000	16,000	737	571
Brown Swiss	16,000	19,300	773	641
Normande	159,000	17,300	692	560
Montbeliarde	323,000	18,800	675	582

Some of the figures in the Table 1 may surprise US dairy breeders. Population sizes for Normande and Jersey are similar, while Montbeliarde are twice as numerous as Jerseys. These two breeds have strong young sire programs in France. Pictures of the French breeds suggest a recent dual-purpose heritage, but the production figures, which are intermediate between Swiss and Jersey, certainly say that these are dairy cattle. One weakness of the Jersey breed is the value of male calves born. Male calves sired by those French breeds should be more valuable. Breeders need to understand that, at this point, there are no scientifically controlled research studies available to evaluate performance of the French breeds on US Holstein or Jersey females.

Swedish Red and Norwegian Red cattle are also specialized dairy breeds. National genetic improvement programs in those two Scandanavian countries are well established, and supported by milk and fitness recording programs that are superior to the United States. Health traits are quite important in both breeding programs, as is fertility. As is the case with many European breeding programs, emphasis on milk components is much stronger than on milk volume. Also typically of European breeding programs, type has received less emphasis than in the United States and Canada. Again, it is important not to think of the Nordic breeds as a somewhat isolated strain of red Holsteins, because their origins are Finnish Ayrshire and local breeds well removed genetically from US Holsteins. These breeds may prove to be very productive in US crossbreeding programs, but there are no performance records available to confirm or refute that possibility.

I think it only fair to mention the New Zealand Jerseys and Friesians as potential breed resources. Genetic ties between the New Zealand strains and US strains with the same breed name are not strong. New Zealand breeders have not made widespread use of US semen because, primarily, of the size of our cows and the importance of milk components to the New Zealand milk market.. Both of these breeds have been selected under intensive grazing conditions with a lot of emphasis on maintenance costs – interpret that as a big penalty for big cattle. The progeny testing and milk recording programs are quite advanced. New Zealand breeders can identify the genetically superior animals for their management conditions. The question is whether those same animals have anything to offer crossbreeding programs in the United States. More than a few grazing herds in the US are trying New Zealand genetics to see if selection for economic performance under grazing conditions translates into better economic performance under our conditions. Again, we have no current scientifically controlled results to share on how well these crosses perform relative to US Holsteins or Jerseys.

Body Size is an Issue

While we're on the subject of size, our selection programs in the US have favored bigger cows. Purebred animals from modern selection programs have tremendous appetites. We have practiced within breed selection for high yields on full feed where the big appetite meant more milk production. Appetite was a correlated response to selection for higher yield. The "best" cow simply gave more milk than her herdmates when all cows could eat all that they wanted. If she was big, who cared as long as she gave a lot of milk?

The "best" cows on less than full feed would likely be smaller than the cows we have today because they would use less energy on body maintenance and more on production. New Zealand grazing conditions stress maximum yield per hectare grazed, not yield per cow. The "best" cow under those conditions is the cow willing to eat grass right into the roots or willing to shove the cow patties out of the way and eat what's underneath (poor taste buds or refusal to go hungry?). And, yes, she IS a smaller animal than we see in United States confinement dairies. She MAY be more efficient at converting fresh forages into milk than US cows are at converting preserved forages and grains into milk. Where might cows selected for performance under such conditions fit in the US dairy farms of the future? Restricted feedstuffs are unlikely in this country and probably won't reverse the trends for bigger cows, but herd health issues very well could. The big cow is a problem in many confinement systems. She just doesn't wear as well as the more compact models. But size is an emotional issue. The advantages of smaller cows need to be pretty clear before changes will occur.

Within Breed Selection

Breeders who decide to try crossbreeding really should use the best bulls available in the sire breed(s) they use in their program. We expect average purebred daughters of two Brown Swiss bulls whose PTA's for milk yield to differ by 1,000 lbs. to differ by 1,000 lbs. In the absence of specific scientific evidence to the contrary, we should expect crossbred daughters to differ by the same amount. The daughters of the bull with the higher PTA for milk should give more milk because they will inherit their production genes from that bull's proven superior genotype.

Crossbreeding does provide a hypothetical basis for that 1,000 lb. difference to change. What if one of those Brown Swiss bulls was more closely related to his mates during progeny testing than the other bull? The 1,000 lb. difference in PTA would be affected, however slightly, by the higher average inbreeding of his progeny. On mates from another breed, none of that inbreeding depression would be expressed, and differences between the two bulls could change slightly. It is also possible that one bull may produce more heterosis than another, even when mated to a very large number of random mates from another breed. These factors are not likely be nearly so important as the genetic differences between bulls within a breed. My advice to producers is to take advantage of superior genetics any way they can get it, and good sire selection clearly is one such way.

Heterosis

The Animal Improvement Programs Laboratory of USDA in Beltsville, MD, the group that calculates the USDA genetic evaluations, maintains national production records on all breeds and crossbred animals. Table 2 below shows the relatively small number of crossbred animals by different breed combinations currently in the national records files. There are other breed combinations like Brown Swiss – Jersey, but the numbers are very small. The animals that contributed to the results in Table 2 were properly identified by sire and dam, and had a valid date of birth associated with their production records. Crossbreeding is much more widely practice than the numbers in the table would suggest, because accurate identification has not been encouraged for crossbred cows. Also, the various systems used by the DHI records processing centers are not necessarily well adapted to recording and reporting crossbred information. This attitude toward crossbreeding needs to change immediately in order for us to evaluate the performance of various crosses relative to purebred cows.

Table 2. Size of national data files and percent heterosis for milk yield for crossbred cows born since 1990.

	Holstein Sire		Holstein Dam	
Breed	Number of offspring	% heterosis, milk	Number of offspring	% heterosis, milk
Ayrshire x	477	2.4	145	-2.0
Brown Swiss x	242	5.6	819	3.2
Guernsey x	1228	5.2	130	2.4
Jersey x	507	7.5	1631	1.6

While the results are VERY preliminary, they do show that heterosis for milk production is positive in almost all cases. Interestingly, heterosis was higher when Holstein sires were used than when Holstein dams contributed their genes to crossbred calves. Heterosis was highest for Jersey cows bred to Holstein sires, at 7.5%. What does that 7.5% mean? It means that production in the crossbred animal was 107.5% of the average production of the two parental breeds. The crossbred calf was better than the average of her parents. The actual milk records showed that Holsteins still gave more milk – just like in the studies performed in the 1950's. What we really need to examine, though, is not heterosis for milk yield, but lifetime economic merit of crossbreds relative to purebreds out of parents with the same genetic merit. To do that, we need some research herds . . . . .

Experiments in the Works

Crossbreeding experiments are beginning at several universities around the country. University of Minnesota began mating Holstein cows at two research herds to Jersey sires last fall and winter. They have calves on the ground, and matings continue. The University of Wisconsin plans some similar JH matings this fall. Another group of universities in the south are planning a different kind of study, with matings to begin in Fall 2002. Tennessee, Kentucky, Virginia Tech and hopefully NC State will be breeding Holstein and Jersey cows to Holstein and Jersey bulls to produce four groups of animals: Holstein sired calves out of Holstein dams, Jersey sired calves out of Holstein dams, Holstein sired calves out of Jersey dams, and Jersey sired calves out of Jersey dams. Plans are for each of the foundation sires and dams (of the pure breeds) to have equal probability of contributing offspring to each of the two groups to which each breed and sex could contribute.

This kind of mating scheme is called a diallele cross. It allows researchers to test whether heterosis is different when Holstein-Jersey crosses are out of Holstein dams or Jersey dams. Table 2 suggests that we ought to look at that question. We will also be able to track crossbred performance against both pure breed groups on a true contemporary basis. Results for the question of lifetime economic merit will be a number of years in the future, but calf performance information will be available much sooner. We expect crossbred calves to have advantages over the purebreds, as many of those calfhood traits are traits that have responded well to crossbreeding in beef cattle and other species. We should also expect milk production to be highest for pure Holsteins. That has been the result every time a trial was conducted. However, when heath, reproductive performance, survival, mastitis, feed bunk behavior, and so forth are factored into a lifetime economic function, the superiority of yield of Holsteins may not be enough to make them the most profitable group.

Conclusions

Crossbreeding has the potential to improve lifetime economic performance over purebred mating systems. Many of the advantages of crossbreds may be expressed during heifer rearing. Producers who do not keep close track of calf survival, growth, fertility, and calving ease may fail to recognize the value of superior performance during rearing. Even if heifer development is not viewed as part of cow performance, multiple component pricing systems, increasing value of reproduction, health, and fitness traits relative to production, and the increase in inbreeding caused by effective within-breed selection programs will make crossbreeding appealing to at least some commercial producers. Good statistics on the relative merit of pure and crossbred breed groups will allow us to put numbers on the various advantages and disadvantages of crossbreeding. Following are some important points to consider prior to starting a crossbreeding program:

- Before starting a crossbreeding program, producers should decide whether future replacement animals are to be produced by the present generation of crossbred dams, from purebred cows on the farm, or purchased from an outside source. That decision will dictate the structure of the crossbreeding plan to be followed.

- Early success from crossbreeding should be expected in the first generation where heterosis is maximized and "first choice" breeds are combined. Continued success depends on a sustainable crossbreeding system.

- Producers should use genetically superior, progeny tested AI bulls from the pure breeds in their crossbreeding programs. At some point in the future, the industry may progeny test crossbred bulls in sufficient numbers for selection to be effective. I don't see the economic incentive for bull studs to make that investment at this point.

- Producers should start crossbreeding programs with reasonable expectations and a clear goal in mind. It is a lot easier to start crossbreeding than it is to undo it.

Those who wish to read more about crossbreeding may be interested the following textbooks, listed in order of increasing technical detail. There are others on the market, but these will keep you out of trouble!

1. "Understanding animal breeding", 2nd edition, by Dr. Richard Bourdon, published by Prentice Hall, ISBN 0-13-096449-2

2. "Genetics for the Animal Sciences" by VanVleck, Pollak, and Oltenacu, published by W. H. Freeman and Company, ISBN 0-7167-1800-6

3. “Introduction to Quantitative Genetics”, fourth edition, by Falconer and Mackay, published by Prentice Hall, ISBN 0582-24302-5