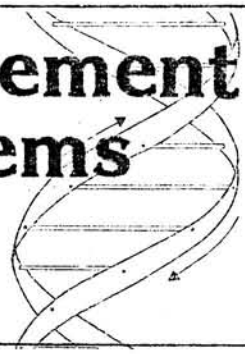
Genetic Improvement Mating Systems

by Darrell L. Wilkes
and Dr. Thomas B. Turner
The Ohio State University



To date this series has dealt primarily with selection. And although selection is obviously extremely important in genetic improvement, the mating system used by a cattle breeder also plays a critical role. With that in mind the authors discuss both random mating and the non-random sytems of inbreeding, linebreeding and outbreeding as well as mating on the basis of phenotype.

Let's begin this segment by differentiating mating systems from selection. Up until now we have dealt primarily with selection; that is, identifying the best males and females to use as parents of the next calf crop. Assuming those selections have been made we now are charged with a decision: Which bull do I mate to which cows or which mating system will I use?

Words that should come to mind are inbreeding, linebreeding, outcrossing, outbreeding and others. We find ourselves reading about these systems and even claiming to use them—one or all—without really understanding the genetic consequences in either the short or the long run.

This brings us to what we feel should be an area of interest to all Angus breeders whether their herds are large or small. Namely, can mating systems introduce bias into progeny records of cows or bulls so we will make errors in our selection program?

Selection and mating can affect one another but really are not related. (Later we will be talking about mating best to best, and worst to worst, etc.) Keep in mind we are discussing previously selected individuals which, although they are as a group the best of what we have to choose from, still vary among themselves so we may talk about the "worst" of this "best" group.

In discussing potential mating systems we will follow this textbook outline:

I. Random Mating
II. Non-Random Mating
  A. On the basis of pedigree relationship
    1. Inbreeding
    2. Linebreeding
    3. Outbreeding
  B. On the basis of phenotypic relationship (assortive mating)
    1. Mating like to like (positive assortive)
    2. Mating unlikes (negative assortive)

Mating systems can have an effect on various traits in the herd, but more importantly, a knowledge of mating systems will aid the breeder in assessing the genetic content of the herd. Certainly, everyone talks of a "breeding" bull or prepotency. And the era of embryo transfer behooves us to know, with greater accuracy, which females will tend to "breed true." A knowledge of mating systems should improve our level of knowledge in making these educated guesses.

Another point to clarify at the outset is that of relationship, because mating systems, in part, are based on relationships. We can take several views here. Obviously, all cattle are related with many things in common; however we generally do not assume that dairy cattle are related to beef cattle. Where do we draw the line? Where do we break off the family tree? Consider the question of whether a particular Angus bull is related to a particular Angus cow. If the base considered is a single herd, the two might be considered unrelated but if the base is the entire breed they may indeed be considered related. For the purpose of this article we will be using either the breeder's herd or the entire breed.

Random Mating

Random mating is often dismissed as careless or reckless or simply the lack of a definite plan. This is **not** the case. This mating, by definition, occurs when cows are randomly assigned to bulls ignoring any genetic likeness or similarities with respect to traits that are measured or observed in the cattle. This system would tend to result in an average amount of variation in the calf crop. (We will see later that other mating systems can increase or decrease variation for type or performance traits.)

With the random mating system we would expect no contribution to performance, either plus or minus—as can be the case with other mating systems. This can be an advantage if we wish to measure progress due to selection free from any bias that might be introduced by the mating system. For example, any breeder knows that an average bull can be made to look good by mating him to the best cows and the opposite would be true also. This being the situation, how can we compare cumulative cow records fairly when cow A has a calf each year by the best bull available while cow B has been serviced by the cleanup bull each of those same years? Is the superiority of cow A due to her genetics or to those of the bulls?

Non-Random System: Inbreeding

Inbreeding is a non-random mating system based on pedigree relationship. When mates are related through common ancestors the resulting offspring are said to be inbred. Inbreeding by definition is the mating of animals more closely related than the average of the population. Inbreeding is commonly misunderstood and sometimes feared as something wrong or bad. Conversely, inbreeding should be looked at objectively as a tool for potential use in your breeding program depending on your current level of performance with respect to the traits for which you are selecting. Your confidence in inbreeding as a tool should be bolstered when you consider the progress made in corn yields since the production of hybrid seed—the end result of an intense inbreeding system. Let's examine what inbreeding is and whether or not you should consider it as a tool in your program.

If we consider a single trait controlled by a pair of genes (A and a) we can have three genotypes: AA, Aa and aa. These can be present at any level in the herd. Inbreeding will increase the AA and aa genotypes at the expense of Aa genotype. As a result, variation of this calf crop will be greater than the average we talked about under random mating. Conversely, variation for traits within a family in a herd will be reduced as a result of inbreeding. Furthermore, because the heterozygote or the Aa genotype tends to be better than the average of the two homozygotes (AA and aa) we have reduced average performance. This is true for traits that are lowly heritable such as reproduction. There is little effect on highly heritable traits such as feed efficiency or carcass traits.

Cattle have many thousands of gene pairs with many genes affecting each of the economically important traits. If we were to determine that a bull was 25% inbred he is expected to possess 25% fewer heterozygous gene combinations (Aa) than the average of the population. The inbreeding coefficient (commonly referred to as a percentage) measures the loss of heterozygosity and not the amount of homozygosity. Angus cattle are obviously homozygous for some of their genetic material or else they would not be recognized as Angus.

Inbreeding does not make cattle better or worse, just as performance testing does not make cattle better or worse. Inbreeding does, however, make cattle more predictable as a result of this increased level of homozygosity (AA and aa). We commonly

call this predictability prepotency. Certainly, this consistency contributes to breed progress. It has been said that a consistently bad bull does less damage to a breed than the bull who has produced one great offspring and many poor ones. The former bull will be quickly discarded while the latter will be kept, in many cases, in the hopes he will sire another great one.

An important task in cattle breeding today involving inbreeding is that of uncovering deleterious or undesirable recessive genes. Remember, most recessive genes will only exhibit their trait when paired, so homozygosity is essential. Inbreeding increases homozygosity and therefore aids us in finding these less than desirable genes. Many breeds are actively purging their populations of certain of these and the breed publications regularly contain lists of known carrier bulls, many of which were discovered by mating them to their own daughters, the most intense form of inbreeding.

Non-Random System: Linebreeding

Linebreeding is a word familiar to all cattlemen, understood by some and used by few. What is linebreeding and why is it more accepted as a mating system than inbreeding? To begin with, linebreeding is a form of inbreeding. In this case the breeder attempts to concentrate the influence of a particular outstanding individual, usually a sire. The reason is that males generally leave more offspring than females and there is a greater opportunity to select individuals in that sire line. The theoretical objective would be to make the herd genetically identical to this outstanding individual. In doing this, inbreeding occurs since these animals are more closely related than the average of the population. However, the goal or design is not to inbreed but to achieve a high genetic relationship.

In most linebreeding systems, an attempt is made to hold the level of inbreeding as low as possible. This is accomplished by using as parents animals which are closely related to the admired ancestor but are little if at all related to each other through any other ancestors. Ordinarily, in a non-linebred population, the expected amount of inheritance from an admired ancestor is halved each generation. Linebreeding provides a mechanism for retaining a higher level of this superiority for a longer period of time.

As with any other type of inbreeding, there is an increased chance that some specific desirable genes will be lost when linebreeding is used. Without using cattle from outside the line, there is no way to get these genes back once they are lost. This has led to the demise of many linebreeding systems. At the time the line was formed, the ideal animal may have been quite different than at the present time. Hence, genes once thought to be undesirable but currently considered desirable, may not exist in the line.

The final word on linebreeding should be obvious; that is, it should be practiced only when there are no other animals in the breed which are superior to yours. Once a breeder has reached this upper echelon, he or she should by all means begin a linebreeding system.

Linebreeding is probably overemphasized in breeding cattle. In an earlier article about gene action, we mentioned that for the economically important performance traits we have mostly additive gene action. This means that each pair of genes acts independently and, as a result, an attempt to make cattle genetically like a sire by using his offspring as parents is not very fruitful. This is especially true when dealing with traits of high heritability.

Non-Random System: Outbreeding

Outbreeding is the practice of mating cattle less related than the average of the population. Many breeders, in the case of outbreeding, consider their herd as the population base, which is fine, and we commonly say a breeder is outbreeding when he uses a bull with no known relationship to his cow herd. Crossbreeding would be the most extreme example of outbreeding.

The effect of outbreeding is the opposite of inbreeding in that the resulting calf crop is generally slightly more uniform as a result of reduced homozygosity. Many breeders, with a knowledge of hybrid vigor or heterosis from crossbreeding experience assume that some hybrid vigor will result when outbreeding within a breed (sometimes called outcrossing). Although an increase in heterozygosity is possible, the improved performance is so slight that breeders using outcrossing to improve performance could be using their energies in more fruitful areas of genetics.

There is a common belief among purebred cattle breeders that some lines of cattle cross better on some lines than they do on certain other lines. Frankly, this is a misconception. There are only three or four actual lines of linebred cattle in the Angus breed today. However, because of the common practice of naming heifers after their dams, any female with the name Blackbird, for example, is thought to be a member of the Blackbird **line**. There is no doubt that a Blackbird line once existed, but after many generations of mixing the original lines of Angus cattle, no true Blackbirds exist today. Hence, any effort made by a breeder to avoid mating a Blackbird heifer to a bull out of a Blackbird dam, simply to avoid inbreeding, is wasted. In terms of human population, if your name is Smith would you forbid your daughter to marry a man just because his name was also Smith? Probably not. Chances are, they have a common ancestor, but then, don't we all?

For the most part, outcrossing is an over used and obsolete term. Crosses between the few genuine lines which do exist may give a little heterosis but we would not go to the bank on it.

Phenotypic Relationship

Mating on the basis of phenotype is divided in our outline into two kinds—positive assortive and negative assortive. By definition, positive assortive mating describes the mating of like to like while negative assortive denotes the mating of unlikes. While the definitions are very tidy, they cannot totally describe the mating of one animal to another. Let's suppose you're selecting for frame score and you've chosen the 50 tallest heifers and the two tallest bulls to be parents. If you mate the tallest bull to the tallest 25 heifers and the shortest of bulls to the shortest of the 50 heifers, you have positive assortive mating for frame score. However, given these 50 matings, what type of mating did you have for type score or yearling weight? As you can see, it gets complicated. Constructing an index which considers all traits may solve some problems but it creates new ones.

The problem with an index is that it can inadvertently let a component trait fall below acceptable levels. You will recall that an index yields one number as a basis upon which to rank animals. Once that index has been calculated, and you head for the office to plan the matings, you don't know whether an animal has a high index because of trait A, trait B and so on. As an analogy, our friends from the IRS aren't satisfied with only the bottom line filled in on the tax form. They want to know if you lost money on your corn, made money on your cattle and so on. Also, by evaluating your own tax form piece-by-piece you can decide specifically where you need to make changes. If you judge your fiscal success based only on the bottom line, you may choose to keep that corn ground never knowing that it was a detriment to your ultimate success. The same is true in cattle breeding. You may be improving yearling weight very successfully but all of your bulls are so sickle-hocked or post-legged they can't be sold as breeding bulls. However, because they have a high index value due to yearling weight, they are used as parents. And the problem is not solved.

The most palatable suggestion we can offer with regard to phenotypic assortive mating is that positive assortive mating be practiced for those traits which, at least to some degree, follow the pattern of "the more the better." Negative assortive mating would probably be utilized best for those traits which have their optimum somewhere around the average (example: set to the hind legs).

On the other hand, if the perfect bull can be found, use him on all your cows. Incidentally, if anyone comes across the perfect bull, please let us know. We're in the market for one.

In summary, mating systems play a critical role in our breeding program and sometimes one that can result in the masking of information critical to us from the selection standpoint.

Certainly, our procedures to aid breeders will improve in the future, but for today the progressive must consider the options.