CHAPTER 12

Animal Breeding Systems

SYSTEMS OF BREEDING

There are two basic systems of breeding in livestock production: (1) straightbreeding and (2) crossbreeding. Mating animals of the same breed is called *straightbreeding*. Mating animals of different breeds is called *crossbreeding*. Each system has a place in livestock production and is used for a particular purpose. Both have advantages and disadvantages. No one system of breeding is best.

The system of breeding to be used depends on the kind of livestock operation in which the animals are bred. Sometimes, farmers use more than one kind of breeding system. The size of the herd, amount of money available, and goals of the farmer are other factors considered when selecting a system of breeding.

Whenever two animals are mated, either straightbreeding or crossbreeding is used. There are several variations of each system. Straightbreeding includes purebred breeding, inbreeding, outcrossing, and grading up. Several systems of crossbreeding are used. These include two-breed crosses, three-breed crosses, and rotation breeding. These systems are discussed in this chapter.

Purebred Breeding

A *purebred* animal is an animal of a particular breed. The animal has the characteristics of the breed to which it belongs. Both parents of a purebred animal must have been purebred. A purebred animal is eligible for registry in the purebred association of that breed if it has no disqualifications. Disqualifications are listed in the rules for registering animals in the breed association. A common disqualification is color markings that purebred breeders regard as undesirable. These are sometimes the result of recessive genes. To register purebred animals, one must be familiar with the rules for registering animals of that breed. Information may be obtained from the breed association.

The ancestors of a purebred animal can be traced all the way back to the original animals accepted for registry in the herd book of the breed association. There is a tendency for purebred animals to be genetically homozygous. Usually, only a small number of animals were originally accepted in the herd book of the breed association. This resulted in some inbreeding and linebreeding in the early history of the breed association. Inbreeding and linebreeding result in greater homozygosity of the genes in a given line of animals.

(A represents the male; B the female)

1st mating	A × B
1st generation	1/2A1/2B
2nd mating	A × 1/2A1/2B
2nd generation	3/4A1/4B

The offspring in the second generation have received 3/4 (75%) of their genetic inheritance from the sire A because he appears closer in the pedigree to the offspring than he does in linebreeding. They have received only 1/4 (25%) of their genetic inheritance from the female B.

FIGURE 12-1 Closebreeding (sire to daughter).

Purebred animals are not necessarily better than nonpurebred animals. In fact, undesirable recessive characteristics may appear because of the homozygosity of the genes of the parent animals. However, the average purebred animal is generally better than the average nonpurebred animal of the same breed.

The production of purebred animals is a specialized business. Purebred animals provide the foundation stock for crossbreeding to produce market animals. Purebred breeding requires more money for breeding animals than does raising market animals. A purebred breeder usually furnishes foundation stock for other purebred breeders and for those raising market animals. Purebred breeders often show their animals in purebred shows.

Inbreeding

Inbreeding is the mating of related animals. Linebreeding and closebreeding refer to how closely related the animals are that are being mated. The most intensive form of inbreeding is *closebreeding,* in which the animals being mated are very closely related and can be traced back to more than one common ancestor. Examples of closebreeding include sire to daughter, son to dam, or brother to sister (Figure 12-1).

Linebreeding refers to matings of animals that are more distantly related and can be traced back to one common ancestor. Examples are cousins, grandparent to grandoffspring, or half-brother to half-sister (Figure 12-2).

Inbreeding increases the genetic purity of the stock produced. The pairing of the same genes is increased, and the offspring become more genetically homozygous. The result of several generations of inbreeding is a high degree of genetic purity or homozygosity. Undesirable genes and desirable genes become grouped together in the offspring with greater frequency. This makes the undesirable traits more visible. The breeder can then eliminate animals with these traits from the breeding program. Desirable traits also become more

(A represents the male; B & C represent females)

1st matings:	A × B	A × C
1st generation:	1/2A1/2B	1/2A1/2C
2nd mating:	1/2A1/2B × 1/2A1/2C	
2nd generation:	1/2A1/4B1/4C	

The offspring in the second generation have received 1/2 (50%) their genetic inheritance from the sire A because he appears twice in their pedigree. They have received only 1/4 (25%) of their genetic inheritance from each of the females B and C.

FIGURE 12-2 Linebreeding (half-brother to half-sister).

visible. A good program of selection and culling will result in breeding stock with more desirable traits.

Animals with desirable traits that are used for outcrossing usually give better results. It is possible to keep the good traits of an animal in the ancestry of the animals being produced. Inbred animals often transmit desirable genes to their offspring with greater uniformity. The production of inbred lines helps to improve the breed.

Inbreeding requires a carefully planned program of selection and culling. It is expensive because all animals with undesirable traits must be removed from the breeding program. The average animal breeder generally does not find inbreeding a desirable system of breeding to use. It is used more often by universities for experimental work and by seedstock breeders that provide animals for crossbreeding in herds producing animals for market.

Outcrossing

Outcrossing is the mating of animals of different families within the same breed. The animals bred are not closely related. The purpose of outcrossing is to bring into the breeding program traits that are desirable but not present in the original animals. Most matings done by purebred breeders are outcrossing. This system is popular because it reduces the chances of undesirable traits appearing in the offspring. The genes for those undesirable traits are still present. However, they are covered up by the outcrossing. Outcrossing is sometimes used in combination with inbreeding programs to bring in traits that are needed.

Linecrossing is mating animals from two different lines of breeding within a breed. The purpose is to bring together desirable traits from different lines of breeding. Some lines cross better than other lines because of different gene combinations. Experience is the best guide in determining the lines to use when linecrossing.

Grading Up

Grading up is the mating of purebred sires to grade females. Most of the animals on farms in the United States are not purebreds. The mating of purebred sires with these grade animals is a good way to improve the quality of animals on the farm. A *grade* animal is any animal not eligible for registry. It does not require as much money since only the purebred sires (or their semen) must be purchased. How quickly the animals are improved depends on the species of animal. Animals with short generations, such as swine, are improved fairly rapidly. Those with longer generations, such as cattle or horses, take longer to produce improvement.

The amount of improvement that results is dependent on the quality of sire selected for the breeding program. Most commercial producers get their purebred sires from purebred breeders. It is important to select the highest quality sire with performance records that the commercial breeder can afford. Offspring of grading up are

(A_1, A_2, A_3, represent purebred sires of a given breed; G represents a grade female)

1st mating:	$A_1 \times G$
1st generation:	$1/2A_1 1/2G$ (50% purebred, 50% grade)
2nd mating:	$A_2 \times 1/2A_1 1/2G$
2nd generation:	$1/2A_2 1/4A_1 1/4G$ (75% purebred, 25% grade)
3rd mating:	$A_3 \times 1/2A_2 1/4A_1 1/4G$
3rd generation:	$1/2A_3 1/4A_2 1/8A_1 1/8G$ (87.5% purebred, 12.5% grade)

FIGURE 12-3 Grading up (purebred sires on grade female).

generally not eligible for registry in the breed association because only one parent is registered. However, some breed associations do permit the offspring of grading up to be registered. Also, new bloodlines were introduced from other breeds in some associations. A few associations are now requiring blood testing as a part of the registration process. A person interested in registering animals should contact the appropriate breed association to determine the current rules for registration.

The greatest percent of improvement comes in the first cross, since fifty percent of the genes of the offspring will be from the purebred sire. Second-generation offspring will be 75 percent purebred. The third generation will be 87.5 percent pure. If the use of a purebred sire continues long enough, the amount of grade breeding left in the offspring will be less than 1 percent (Figure 12-3).

Crossbreeding

Crossbreeding is the mating of two animals from different breeds. The resulting offspring is a hybrid. Crossbreeding usually results in improved traits in the offspring. Dominant genes tend to mask undesirable recessive genes.

Superior traits that result from crossbreeding are called hybrid vigor, or heterosis. Heterosis is measured by the average superiority of the hybrid offspring over the average of the parents. The kind and degree of superiority achieved by crossbreeding varies with different species. Traits with a high degree of heritability show little improvement from crossbreeding; those traits with low heritability usually show the greatest improvement as a result of crossbreeding.

An accurate estimate of heterosis may be made only when a large number of matings are made and the environmental conditions under which the animals involved are raised are as similar as possible. The following formula is used to make an estimate of the percentage of heterosis achieved:

$$\% \text{ Heterosis} = \frac{\text{Crossbred average} - \text{straightbred average}}{\text{Straightbred average}} \times 100$$

The percentage of heterosis for weaning weight resulting from crossbreeding two breeds of beef cattle may be determined from the following hypothetical data:

- Average weaning weight for breed A = 448 pounds.
- Average weaning weight for breed B = 460 pounds.
- Average weaning weight for crossbred calves = 475 pounds.

The straightbred average weaning weight is 454 pounds [(448 + 460) ÷ 2 = 454]. Substituting in the formula:

$$\% \text{ Heterosis} = \frac{475 - 454}{454} \times 100 = 4.6\%$$

Animals selected for use in a crossbreeding program must have the desired traits. There will be little or no improvement in the offspring over the parents if animals with undesirable traits are used in a crossbreeding program. Regardless of the crossbreeding system used, the producer must follow a good performance selection program, good management, good nutrition, and good herd health practices to achieve the desired results. Research has shown that well-planned crossbreeding programs can increase total productivity in beef herds by 20 to 25 percent.

Beef, swine, and sheep producers usually use crossbreeding for the production of market animals. It is rarely used by dairy producers because they are primarily interested in milk production and the Holstein breed, which is superior to other breeds in this trait, dominates the dairy industry. Poultry producers typically use strains that have been developed from crossing inbred lines.

Crossbreeding systems for beef. The use of crossbreeding in beef cow herds that produce animals for slaughter will generally result in higher profits. Some general considerations regarding a beef crossbreeding program include:

- good recordkeeping is essential.
- calving difficulties may increase when crossing large breed sires with small breed dams.
- there are fewer calving problems if large breed dams are used.
- large breed dams have higher maintenance costs.
- artificial insemination allows access to better bulls.
- to avoid inbreeding, more than one breeding pasture may be required.

Some experimental results of crossbreeding with beef cattle are shown in Table 12-1.

Crossbreeding systems used with beef cattle range from those that are relatively simple to those that are complex. Some typical beef crossbreeding systems include:

Terminal sire crossed with F_1 females. Replacement F_1 (crossbred) females in the herd are purchased and crossed with a terminal bull. All the offspring are marketed.

Rotate herd bull every three or four years. The same breed of bull is used for several years then replaced with a bull of a different breed. Replacement females are selected from the herd.

Two-breed rotation. Bulls from breed A are crossed with cows from breed B. The resulting heifers are bred to bulls from breed B for the

TABLE 12-1 Crossbreeding Effects in Beef Cattle.

Trait	Percent Advantage over Noncrossbred Cattle (2-Breed Cross)	(3-Breed Cross)
Fertility and percent calf crop	3	7
Weaning weight	5	10
Pounds of calf weaned per cow	6	15
Yearling weight	6	12
Feedlot growth rate	4	5
Carcass traits	0	0
Feed efficiency	0	2

Source: *The F_1 Beef Cow and Crossbreeding*, A2556, University of Wisconsin, 1973.

duration of their productive life. Replacement heifers chosen from these matings are bred to bulls from breed A. Each succeeding generation of replacement heifers is bred to a bull from the opposite breed used to sire the replacement heifer.

Three-breed rotation. The pattern of breeding is the same as in a two-breed system, except that a bull from a third breed is used in the rotation of sires.

Four- and five-breed rotations. In larger herds, bulls from a fourth or fifth breed may be used in the rotation of sires. This system requires a higher level of management than two- and three-breed systems.

Static terminal sire system. Four breeding groups are needed for this system, as shown in Figure 12-4. The first group (25 percent of the herd) mates bulls (breed A) and cows (breed A) to produce replacement heifers (AA) for group one and group two. The second group (25 percent of the herd) breeds the AA heifers to a bull (breed B) of a different breed, producing crossbred heifers (breed AB). The third group (50 percent of the herd) breeds the AB heifers to a terminal (T) bull selected for ability to transmit a high rate of gain. A sub-group (group four, 10 percent of the herd) of the third group is composed of AB heifers being bred for the first time. These AB heifers are bred to a smaller breed (breed C) bull to reduce first-time calving problems. All the male offspring of groups one and two and all of the offspring of groups three and four are marketed. Any heifers from groups one and two that are not kept for breeding purposes are also marketed.

Rotational-terminal sire system. Two breeding groups are needed for this system. Bulls from breeds A and B are used on a rotating basis on 50 percent of the herd, providing crossbred females for the entire herd. Mature cows in the herd are mated with a terminal bull to produce offspring, all of which are marketed. Replacement females generally come from the matings of bulls A and B with younger cows in the herd.

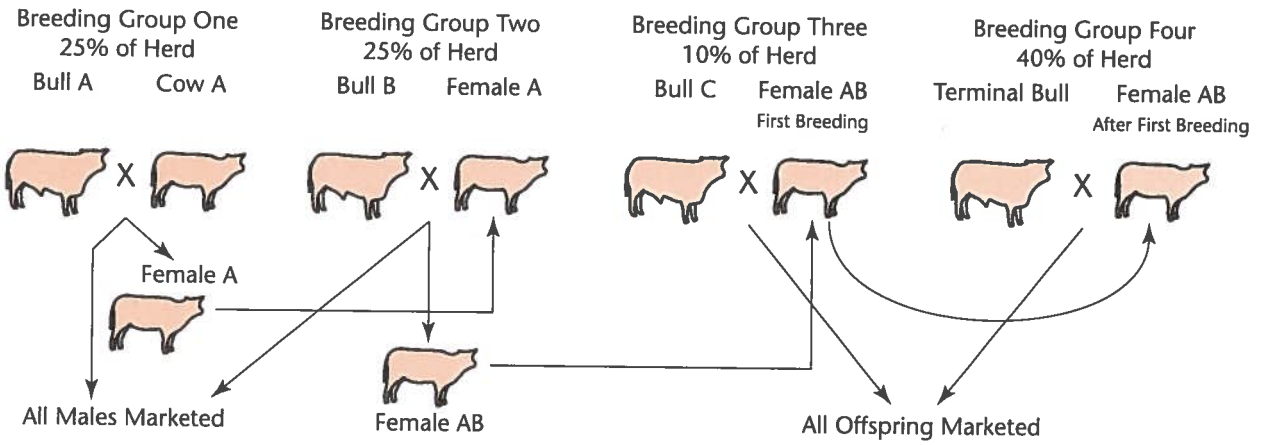


FIGURE 12-4 Static Terminal Sire System.

Composite breeds. The development of a new breed based on crossbreeding with four or more existing breeds of cattle to avoid inbreeding problems. After development, the composite breed is not crossbred with other breeds.

Crossbreeding systems for swine. Some general considerations related to a swine crossbreeding program include:

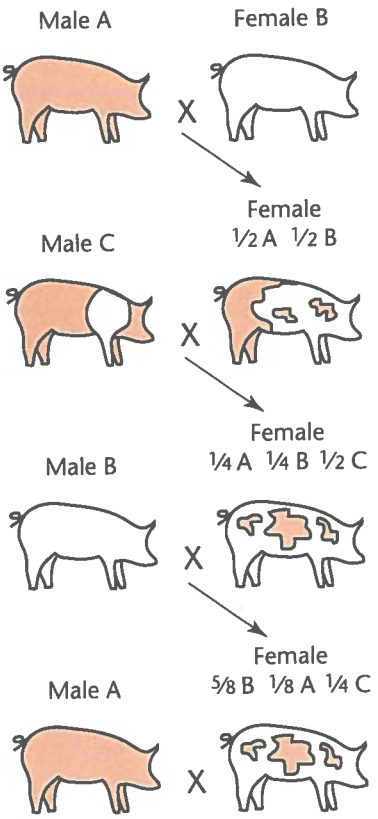
- select breeds to use and replacement gilts and boars that meet the objectives of the breeding program.
- select breeds that produce large litters and heavier weaning weights if they are to be used only on the female side of the matings. The white breeds are generally superior in these traits.
- select breeds that have less backfat and higher rate of gain if they are used as terminal boars in the crossbreeding program. The Berkshire, Duroc, Hampshire, Poland China, and Spotted breeds are generally superior in these traits.
- if crossbred sows are used, select those that are at least 50 percent Chester White, Landrace, or Yorkshire. These crosses generally have the superior maternal traits that are desirable.
- select boars that are from sows that rank in the top 25 percent of a herd, as measured by a Sow Productivity Index. Growth rate and backfat thickness are important considerations when selecting boars.
- crossbred boars may be used in a crossbreeding program. Be sure their parents have desirable traits that fit the objectives of the program.

Some experimental results of crossbreeding systems with swine are shown in Table 12-2.

TABLE 12-2 Heterosis Advantage for Production Traits in Swine.

Trait	Percent Advantage Over Purebred: First Cross Purebred Sow	Multiple Cross Crossbred Sow	Crossbred Boar
Reproduction			
Conception rate	0.0	8.0	10.0
Pigs born alive	0.5	8.0	0.0
Litter size 21 days	9.0	23.0	0.0
Litter size weaned	10.0	24.0	0.0
Production			
21-day litter weight	10.0	27.0	0.0
Days to 220 lb.	7.5	7.0	0.0
Feed/gain	2.0	1.0	0.0
Carcass composition			
Length	0.3	0.5	0.0
Backfat thickness	–2.0	–2.0	0.0
Loin muscle area	1.0	2.0	0.0
Marbling score	0.3	1.0	0.0

Source: Ahlschwede, W.T., C.J. Christians, R.K. Johnson, and O.W. Robison, *Pork Industry Handbook*, "Crossbreeding Systems for Commercial Pork Production," University of Illinois.



A, B, and C represent different breeds. Continue using males of three breeds in sequence. Using males of the three breeds in sequence is called rotating the males; hence, the inclusion of the term *rotation* in the name of this system.

FIGURE 12-5 Three-breed Rotation Cross.

Some typical swine crossbreeding systems include:

Rotational crossbreeding. In *two-breed systems,* a boar from breed A is mated with sows from breed B, producing offspring AB. Selected gilts (AB) are bred to a boar from breed B. Selected gilts from this mating are bred to a boar from breed A. The pattern is repeated, switching back and forth to the breed of the most distantly related boar. *Three-* or *four-breed systems* are more commonly used in swine production. The pattern is the same as that used in the two-breed system except that three or four breeds of boars are used in rotation, as shown in Figure 12-5.

Care must be taken to follow the planned order of breeds used in the rotation, or heterosis will be reduced. Because replacement gilts are selected from within the herd, the chance of bringing disease into the enterprise from purchased breeding stock is greatly reduced.

Terminal crossing system. Crossbred (F_1) females, with superior maternal traits, are bred to boars selected for desirable backfat and rate of gain. All of the offspring go to market. The breeder must either keep a separate herd to produce breeding stock or purchase replacement females. The costs involved in this breeding system are generally higher than in rotational breeding systems. There is some increased health risk if new breeding stock is brought into the herd. Terminal crossing does maintain the maximum advantage of heterosis and breed differences in the breeding system.

Rotaterminal system. The rotational breeding system and the terminal breeding system are combined in this method of crossbreeding. Crossbred females are produced by breeding boars of different breeds in a rotating pattern to crossbred females produced by previous matings in the system. Generally breeds with good maternal traits are used to produce the crossbred females that are bred to terminal boars of other breeds. Terminal boars are selected for desirable backfat and rate of gain. All the offspring produced in the terminal breeding go to market. This system of crossbreeding maintains a high level of heterosis and allows the producer to select breeds with desirable traits. It does require the use of more boars of different breeds.

Crossbreeding systems for sheep. The use of crossbreeding generally increases profits from sheep flocks. Crossbred ewes are hardier, healthier, and produce more milk as compared to non-crossbred ewes. A twelve-year study of crossbred sheep conducted at the Agricultural Experiment Station, University of Idaho, revealed that they produced higher grease (uncleaned), as well as cleaned, fleece weights compared to non-crossbred sheep.

Some typical sheep crossbreeding systems include:

Rotational. The same breeding pattern is used as in beef or swine rotational systems. The lambs are usually kept for flock replacements.

Static. Replacement crossbred ewes for the flock are purchased and bred to a terminal ram. All the lambs are marketed.

Roto-static. A combination of rotational and static crossbreeding systems in which replacement ewes are produced from the flock. These ewes are bred to a terminal ram to produce market lambs. It takes about 25–30 percent of the flock to produce the replacement ewes. The best ewes should be kept for producing replacement ewes.

REVIEW

1. Define straightbreeding and crossbreeding.
2. What is purebred breeding?
3. Define and give two examples of inbreeding.
4. Why is inbreeding more commonly used by universities and seedstock producers than by the average livestock producer?
5. Define outcrossing and tell why it might be used in a breeding program.
6. What is linecrossing and why might it be used?
7. What is grading up and why might it be used?
8. Why is crossbreeding used in breeding programs?
9. Name and briefly describe four systems of crossbreeding that might be used in breeding programs.

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