Chapter V

SYSTEM OF MATING

I. Relationships and Inbreeding

There are two kinds of decisions that animal breeders must make:

A. Selection decisions:

- **They must decide which individuals become parents,**
- **How many offspring they may produce, and**
- **How long they remain in the breeding population.**

B. A mating system:

Breeders must also decide which males to breed to females.

A knowledge of mating system is important because producers can utilize them to preserve genetic superiority and utilize hybrid vigour.

- Systems of mating constitute breeding plans that are designed to combine the genes in a population into the most advantageous genotypic combinations. This is done without changing gene frequencies, since a system of mating by itself will not change gene frequency.

- For this reason a system of mating should seldom if ever be used without selection.

- The combination of these 2 procedures, a system of mating accompanied by effective selection, is a powerful tool for genetic improvement.

Since mating systems are based on the relationship of animals being mated, it is important to understand more detail about genetic relationship.

Two methods, the tabular method, which simultaneously accounts for relationship among all animals and which is computationally easy, and the path coefficient method, which is intuitively more understandable, will be described.

Genetic relationship:

Definition :

Relationship refers to the proportion of genes that two individuals have in common because they are members of the same family.

In other words, relationship is best described in knowing whether the genes in an animal or animals exist primarily in a heterozygous condition.

Type of relationships:

1.Direct relationship

Direct relationship has a proportion of their genes in common because one is an ancestor of the other or one is a descendent of the other.

An individual is a direct relative of his or her parents, grandparents, great grandparents, and so forth. In figure below individuals A, D and A, G are examples of direct relationship.

A, G are examples of direct relationship.

2.Collateral relationship :

Collateral relatives are those that are related because they have one or more common ancestors.

In figure below full brother or sisters C, D have two common ancestors (A, B) - they both have the same two parents. The genes that full sibs have in common were obtained from their sire and dam.

RCD = collateral relationship.

Importance of knowing relationships:

Knowledge of relationships can be helpful in:

a. Selecting animals on the basis of relative's records as the relationship coefficient measures the fraction of like genes shared by two animals and thus is an indication of how reliable one of the relative's records will be in predicting the genetic value of the other animal.

b. Arranging matings to avoid high levels of inbreeding as the inbreeding coefficient of an animal is calculated as one half the additive relationships between the parents. Linebreeding is a system of mating which maintains close relationship to particular animal and

c. Establishing lines tracing to desirable animals.

Uses of relationship:

1. When an animal offered for sale and has a pedigree similar to that of another animal that sold earlier at another sale for a high price, and the breeder wants to know the maximum that he should bid for this animal.

2. When a livestock breeder have the chance to buy two animals, one of which shows excellent type and comes at a high asking price and the other of which is lacking in some one point but not to the extent to warrant disregarding the animal entirely. If they have a high coefficient of relationship, one would probably perform just as well in the breeder's herd as the other. He could purchase the cheaper animal and produce as good with it as with the one that was more expensive.

3. For traits such as carcass quality that can not measured very well until after the death of the individual, the slaughter of a relative should give some indication of the carcass quality of the individual in question.

The value of the relative in the respect would be proportional to the degree the two individuals were related. A full brother or sister would be worth more than a half sister or brother in this respect. Full brothers and sister within an inbred line would be more closely related than would be full brothers and sisters that are not inbred.

Relationship coefficients would give a good indication of the value of records of relatives from this standpoint.

Computing and defining relationship using path tracing method (path coefficient):

Relationship is based on the fraction of 1/2. One half is used because of the having of the genetic material as it is passed from parent to offspring.

The formulas used for computing the relationship between two animals (X and Y) are:

$$R_{XY} = \frac{(1/2)^{n+n}\ (1+FCA)}{\sqrt{(1+Fx)(1+Fy)}}$$

Where:

R_{xy}: is the relationship coefficient between animals X and Y.

$\sum$ is the Greek symbol meaning to sum or add.

n: is the number of generations (arrows) from ancestor to one of the animals for which relationship is being computed.

n: is the number of generations (arrows) from ancestor to the other animal for which relationship is being computed.

FCA: is the inbreeding coefficient of the common ancestors.

F_X: is the inbreeding coefficient of the animal X.

F_Y: is the inbreeding coefficient of the animal Y.

Animals are more closely related than the average of the population when they have common ancestors within the first five generations of their pedigree.

Common ancestors beyond five generations contribute very little increased genetic similarity when compared to the genetic relationship of two animals chosen at random from the same population (e.g. breed).

Classification of system of mating:

System of mating has been broadly divided into:

1. Closebreeding : which is the mating of related animals,

2. Outbreeding: which is the mating of unrelated animals.

The closebreeding and outbreeding can be classified into:

Close-breeding (mating relatives)	Out breeding (mating non-relatives)
Inbreeding Linebreeding	Crossing species Crossbreeding Out crossing Back crossing Top crossing Grading up Mating likes Mating unlikes

I. Closebreeding (mating relatives):

1. Inbreeding:

Definition:

Inbreeding is the mating of animals that are more closely related to each other than the average relationship in a population.

As a rule of thumb, inbreeding usually involves individuals that are at least as closely related as second cousins that are, having a minimum relationship coefficient of 3.125.

Importance of inbreeding:

1. Inbreeding is another tool, in addition to selection, that the animal breeder may use for the improvement of farm animal.

2. The inbreeding has been used in the past especially in the early development of some breeds of livestock.

Different forms of inbreeding:

1. **Intensive inbreeding**: mating of closely related animals whose ancestors have been inbred for several generations.

2. **Linebreeding:** a mild form of inbreeding where inbreeding is kept relatively low while maintaining a high genetic relationship to an ancestor or line of ancestors.

The genetic effect of inbreeding:

The genetic effects of inbreeding is to increase the number of pairs of genes that exist in the homozygous state regardless of the kind of gene action involved.

So it is very important to understand how homozygosity is brought about.

To illustrate the genetic effect of inbreeding, we shall assume the following:

A. We shall use a single pair of genes and let D be the dominant and d the recessive allele.

B. We are dealing with plants that are self-fertilized and that there is no selection for or against the dominant or the recessive genes.

C. The parent generation we are working with contains 1600 individuals, all of which are heterozygous for two genes (Dd).

A study of this example will show that:

1. An important change has taken place in the percentage of homozygous in the population :

A. In the parent generation: all of the individuals were heterozygous (Dd).i.e. no homozygous at all.

B. In the first generation of inbreeding: 50% of the individuals are homozygous dominance (DD) and homozygous recessive (dd).

C. In the second generation of inbreeding: 75% of the individuals are now homozygous dominance (DD) and homozygous recessive (dd).

Continuing this self fertilization, we find that the homozygosity of the population produced increases with each generation but a decreasing rate.

2. Inbreeding did not change the frequency of the genes in the population:

In the parents: the frequencies of both the D and the d genes were 0.50.

In the fourth generation: the frequency of each gene was still 0.50.

3. In animals, the genetic effects are still the same, except that homozygosity increases at a slower rate, depending upon the degree of relationship between parents that produce inbred offspring.

Computation of inbreeding coefficients using path tracing method (path coefficients):

Note that inbreeding is computed on one animal where relationship involves two animals.

1. When a population is closed (i.e. no more genetic variation is introduced from outside) and breeding continues at random, then it is inevitable that there is a slow build up in the level of inbreeding through relatives mating together.

The rate at which the resulting heterozygosity is reduced (or conversely the homozygosity increased) is described by lush's formula:

Where:

$$\Delta F = \frac{1}{8M} + \frac{1}{8F}$$

ΔF = the increase in inbreeding per generation.
M = the number of males in the population.
F = the number of females in the population.

2. When it comes to examination of breeding in individual pedigrees, Professor Sewell Wright's formula is generally used. This is as follows:

$$F_X = (1/2)^{ns + nd + 1} (1 + FCA)$$

Where:

F_X: inbreeding coefficient of individual X or the animal in question.

$\sum$: sum of all independent paths which connect the sires and dams of X.

ns: the number of generation from the sire to the common ancestors.

nd: the number of generation from the dam to the common ancestors.

1: the 1 in the inbreeding formula computes one-half of the relationship of the sire and dam. The relationship of the sire and dam of X, divided by 2, will give the inbreeding of X.

(1 + FCA): 1 plus the inbreeding of the ancestor common to the sire and dam of X. If the ancestor is also inbred, there will be an increased homozygosity of X.

N.B: Remember that although we are concerned with the subject animal of the pedigree, the lines of descent end at the sire and dam. It is because these are related that the subject is inbred. The offspring would not be inbred if the parents were unrelated to each other, even if each parent was itself inbred.

If the common ancestor is not inbred, the formula to be used in calculating the inbreeding coefficient, becomes:

$$F_X = \sum [(1/2)^{ns+nd+1}].$$

Consequences of inbreeding:

1. **The main genetic effect of inbreeding is to increase the number of pairs of homozygous genes in the individual.**

Inbreeding increases the homozygosity of genes because relatives tend to carry the same gene or genes and the inbred offspring is more likely to receive the same gene from each parent as compared to the outbred individual.

The more closely related the parents, the more likely they are to be carrying the same genes and the greater the degree of homozygosity in their inbred offspring.

2. Phenotypically, inbreeding (and thus increased homozygosity) usually causes a decline in traits related to physical fitness. Such traits include the survival ability of the young and the performance of the inbred individuals.

When genes become more homozygous, some detrimental recessive genes that had been previously hidden show up in the homozygous state.

The more intense the inbreeding, the more adverse the effect on physical fitness.

3. Inbreeding tends to pair deleterious recessive genes, which would allow culling of affected and carrier animals. Inbreeding tends to make all pairs of genes homozygous regardless of their phenotypic expression.

Inbreeding does not create new recessive genes, nor does it change the frequency of the appearance of homozygous recessive individuals if recessive genes are present in the original non inbred population.

4. **Inbreeding tends to increase breeding purity.**

Breeding purity means that the individual is more likely to transmit the same genes to each its offspring. This is illustrated in following genotypes:

Individual 1	**Genotype AABBCCDD**
Individual 2	**Genotype aabbccdd**
Individual 3	**Genotype AaBbCcDd**

Individual 1 can transmit only genes ABCD through its sex cells.

Individual 2 can transmit only genes abcd.

Individual 3 can transmit any one of sixteen different combinations of genes to its offspring, which shows that it does not breed true.

Although individuals 1 and 2 transmit only one combination of genes to each of their offspring, individual 1 would be preferred for two reasons:

1. It is homozygous dominant for four pairs of genes, and dominant genes are usually desirable in their effects, whereas recessive genes are usually undesirable.

2. In addition, all of the offspring of individual 1 will be of the same dominant phenotype as that parent for the four pairs of genes involved. Therefore, individual 1 is prepotent because it is homozygous dominant.

A prepotent individual stamps its characteristics on its offspring so that they resemble that parent or each other more that usual. This phenomenon is called prepotency.

True prepotency is likely to be observed only for simply-inherited traits or for highly heritable polygenic traits. When heritability is low, environmental effects influence performance to a much greater degree than genetic effects, overwhelming any consequence of having more uniform gametes.

Some general points:

It is highly desirable to determine the most appropriate rate of inbreeding. The points to consider have been summarised by Lush. The best rate of inbreeding depends on:

1. The skills of the breeder in his selection.
2. The frequency of the undesirable genes in the population.
3. Any linkage between good and bad genes in the stock.
4. The amount of dominance, epistasis and environmental effects that may deceive the breeder.
5. The size of the population.

Professor lush considered that 6% inbreeding was the "stop, look and listen" stage.

Applications and uses of inbreeding:

1. Inbreeding increases the chance of expression of deleterious recessive genes, which would allow to select against deleterious recessive gene that is of economic importance by culling of affected and carrier animals and thereby reducing the frequency of the detrimental genes.

This would require severe culling and might be too costly under such conditions. However, the cost must be balanced against the potential gain.

2. To form distinct families within a breed, especially if selection is practiced along with it.

Selection between such inbred families for traits of low heritability would be more effective than selection based on individuality alone, especially if there were distinct or definite family differences.

Family selection is more effective than in individual selection, because it tends to reduce some of environmental variations that breeders often mistake for those of genetic nature.

3. Inbreeding should be used only for the production of seed stock. But even when the breeder uses it for this purpose, he has to determine how much he can sacrifice in the way of lower production and performance to increase the purity of these breeding animals.

4. To develop lines that can be used for crossing purposes, as is done for hybrid seed corn.

Crossing of inbred lines results in heterosis, however, in most cases compensates for inbreeding depression.

5. **From the reach standpoint, inbreeding is of value to determine the type, or types, of gene action that affects the various economic traits in farm animals.**

If inbreeding effects are very great, the trait is affected by non additive gene action.

If inbreeding effects are very small or nonexistent, the trait is affected mostly by additive gene action.

6. **Mating of unrelated animals always results in non-inbred progeny. If the parents are inbred then their progeny are not inbred.**

II. Linebreeding:
Definition:

Linebreeding is a mild form of inbreeding where inbreeding is kept relatively low while maintaining a high genetic relationship to an ancestor or line of ancestors.

By other words, linebreeding is a mild form of inbreeding in which an attempt is made to concentrate the inheritance of one ancestor, or one line of ancestor, in the linebred individuals.

The ancestor used in linebreeding is usually a male rather than a female, because a male generally produces many more descendents than a female and this allows, greater opportunity to prove this merit by means of a progeny test.

Linebreeding is usually a mild form of inbreeding because the relationship is usually directed toward one ancestor, or one line ancestors, which often involves half–sib mating. If parent–offspring matings are made, however, the inbreeding can be intense.

Illustration of linebreeding:

N.B. The first four pedigrees (1, 2, 3 and 4) more likely to be used after the ancestor was dead, while pedigree 5 illustrates a situation in which linebreeding could be practiced while the ancestor to which line breeding was directed was still alive.

Comparison between ordinary inbreeding and linebreeding:

1. The definition of inbreeding also applies to linebreeding, because line breeding is a special form of linebreeding. However, in linebreeding maintaining a high genetic relationship of an individual is kept close to a particular ancestor.

Inbreeding other than linebreeding is a system of matting in which related parents are mated with no particular attempt to increase the relationship of the offspring to any one particular ancestor in the pedigree.

This concept is illustrated in Figure (4) and Figure (5).

The arrow diagram of the pedigree in figure (4) shows that four different ancestors are responsible for the inbreeding of individual X. The inbreeding coefficient of X in figure (4) is also 0.125 as in pedigree in figure (5), but the inheritance received by individual X from any one ancestor is only about 25%. Thus, in the mating system illustrated in figure (4) no attempt was made to concentrate the inheritance of any one ancestor

2. The genetic effects of linebreeding are the same as those of inbreeding. In addition, linebreeding increases the probability that the linebred offspring will possess the same genes as the ancestor to which linebreeding is directed.

3. When ordinary inbreeding is practiced, the relationship between the sire and dam often depends upon several common ancestors.

It is evident that is more difficult to identify three or four genetically superior ancestors than it is to identify one.

A larger number of ancestors increase the probability of a wider variety of homozygous detrimental recessive genes appearing in the offspring when inbreeding is practiced.

Why breeders favour linebreeding over inbreeding:

1. Because line breeding is usually not so intense.

As a general rule, a sire is not mated to his own daughters when linebreeding is practiced, but half–sib mating are made among the offspring of this particular sire.

The disadvantage of full-sib mating would be that the inbreeding coefficient of the first generation would be 0.25, as compared to 0.125 in the half–sib mating and there would be a possibility of the offspring getting deterimental recessive genes from at least two common ancestors instead of from one ancestor.

2. When linebreeding is used, the inheritance of truly outstanding individuals is concentrated in the pedigree.

3. Linebreeding is often used after the death of the ancestor or when it is no longer available for breeding purposes.

When to linebred:

1. Linebreeding should be used only in a purebred population of a high degree of excellence.

2. Linebreeding is probably most useful when the outstanding individual is dead or not available for breeding purposes.

3. Linebreeding to a particular outstanding male may be practiced by a breeder who does not own the male or cannot purchase him.

If he can purchase one or more high quality sons of the admired sire, this would allow the practice of linebreeding to increase the relationship between the young produced and that particular sire.

A word of caution about **line breeding** is appropriate. It will be **most successful when used:**

a. By breeders, who **recognize its potentialities and its limitations.**

b. By those who **have made a detailed study of the principles of breeding.**

Even in previous instances, success will depend upon **the breeder's ability to find and recognize individuals of outstanding merit.**

Thank You