

Applications of inbreeding and out-breeding; Genetic basis of heterosis (hybrid vigour)

Reproduction is the most important biological function that is performed by the living species. Many reproductive mechanisms have come into function, such as asexual reproduction, sexual reproduction and vegetative reproduction, etc. The most important of these is the sexual reproduction, probably due to the fact that sexual reproduction involves the genic recombination, and nature selects most suitable recombinations out of these. Thus, sexual reproduction may be of many forms, i.e., hermaphroditism, crossing of individuals which are not closely related, inbreeding or self-fertilization etc.

Thus systems of mating encountered in natural as well as man controlled populations of organisms can be divided under two headings:-

1. **Inbreeding** or mating among closely related forms.
2. **Outbreeding** or mating among Unrelated forms.

1. Inbreeding

Definition of inbreeding: The process of mating among closely related individuals is known as inbreeding. There can be different degrees of inbreeding. The self fertilization in plants as in peas and beans is a example of inbreeding. In 1903 **Johannsen** recognized the uniformity that characterized self fertilizing plants grown in the same environment. He called such fertilizing populations as pure lines which breed true without appreciable genetic variation. The cross fertilization in plants and animals affords different degrees of inbreeding based relationship. For example, marriages between brothers and sisters, between the first cousins and second cousins are example showing different degrees of inbreeding. Artificial selection always accompany close inbreeding for the betterment of plants and animals both. In sexually reproducing plants and animals, inbreeding is done so as to retain the desirable varieties of the individuals. But in plants where there is asexual reproduction, if any suitable variety is obtained it can be retained indefinitely. If artificial selection in the breeding individuals is done then individuals with the desirable characters are produced in small number and they will be closely related. Hence, close inbreeding becomes a necessity and in order to retain the desirable quality of individuals close inbreeding is a must in order to keep together the genes that have made the individual out-standing.

Inbreeding comes about into two ways

(a) The systematic choice of relatives as mates and (b) the subdivision of a population into small

subunits within which individuals have little choice but to mate with relatives. Generally, inbreeding is taken as the systematic choice of relatives as mates. An inbred individual is one whose parents are related, that is, there is common ancestry in the family tree. The extent of inbreeding is thus a function of the degree of common ancestry shared by the parents of an inbred individual. When parents share ancestral genes, each may pass on copies of the same ancestral allele to their offspring. An inbred individual can then carry identical copies of a single ancestral allele. In other words, an individual of *aa* genotype is homozygous and if it is possible that the *a* allele from each parent is length of a DNA originally copied from the same DNA of a common ancestor, the *aa* individual is said to be inbred.

The first observable effect of inbreeding is the expression of hidden recessives. Rarely does an outbred zygote receive the same recessive lethal from each parent. Dominance acts to mask the expression of deleterious recessive alleles. But, in the process of inbreeding, during which the zygote may receive copies of the same ancestral allele from each parent, there is a substantial increase in the probability that a deleterious allele will pair to form a homozygous genotype. Inbreeding can result in spontaneous abortions, fetal deaths, and congenital deformities. In many animals, inbreeding can be done normally. These species usually do not have the problem with lethal equivalents. Sometimes, it is falsely believed that as a result of inbreeding, harmful characters appear. No doubt, some harmful characters do appear during inbreeding, but this will not be in case of heterozygous individuals due to the presence of recessive genes and they will appear only when the individual is homozygous recessive. If the race is free of such recessive genes, there will be no harmful characters. Ptolemies of Egypt allowed brother sister marriages for many years to produce from quality of their sons and daughters. Sirens of Nile and Coleoptera were the famous individuals of that race, which were probably the finest quality.

Secondly, decrease in the size and vigour is also recorded with the resultant of inbreeding stock. This too can be eliminated by selecting out the homozygous recessive offsprings leaving only heterozygous ones in the progeny.

Practically inbreeding must be followed by cross-breeding. During inbreeding process, there occurs some loss of productiveness of the breeding stock and this loss, more or less, must be counter balanced by suitable cross-breeding or outbreeding. Even if there is production of good individuals with desired characters, they must be cross-bred in order to see the effect of hybrid vigour. In animals, animal breeders have practised close inbreeding in the superior stocks so as to maintain the improvement of the

characters. But this is practically not possible in human being due to present state of society, so inbreeding is less practised in human beings.

Assortative Mating Vs Inbreeding

Inbreeding has been defined as the mating of related individuals and is thus determined by the degree of genetic relationship between the genotypes of individuals. If not accompanied by selection, it does not lead to changes in gene frequency.

Assortative mating is similar to inbreeding in that no gene frequency change results from assortative mating. Assortative mating is based on phenotypic similarities or differences. Positive assortative mating is the tendency for individuals similar in some trait to mate. It will lead to an increase in the proportion of homozygous, while negative assortative mating tends to produce a greater proportion of heterozygous as compared to mating at random. In neither case will gene frequencies change, unless some form of selection also occurs.

Therefore, inbreeding and assortative mating are similar in that they do not lead to gene frequency change, but they are dissimilar in that inbreeding is genotypic and assortative mating is phenotypic. Both can be distinguished by selective mating, in which certain parental type tend to leave greater number of progeny than others.

Practical Applications of Inbreeding

1. Inbreeding tends to decrease variations within the group, maintains homozygosity and stabilizes the type. Therefore, breeders have, developed a desirable genotype in a group by controlling the matings of the animals within a herd or flock. Registered breeds are obtained in this way.

Inbreeding combined with selection over a period of time has resulted in many valuable breeds of domestic animals. For example:

(i) **Merino 'Sheep** known for producing fine wool are developed in Spain as a result of inbreeding & selection conducted for about 170 years. Rambouillet sheep were developed in France from Merino breed.

(ii) Modern race of horses are the descendents of three **Arabian stallions** imported in to England between 1686 and 1730 and mated with several local mares of the slow and heavy horse type.

2. Because inbreeding produces homozygosity, it increases the chances of expression of deleterious recessive genes because of homozygosity. When a heterozygous individual undergoes inbreeding

for several generations, there are roughly equal chances of homozygosity for both dominant as well as recessive alleles. Since the recessive alleles express themselves only in homozygous state, the homozygosity increases the expression, of harmful recessive alleles to produce defective phenotypes. For this reason in human society, the religious ethics and social norms condemn and ban the marriages between brother and sister and in some human races; the marriage between the first cousins or cousins is prohibited. This is known as inbreeding depression.

INBREEDING DEPRESSION

Plant and animal breeders try to improve their race with respect to certain traits by using the "best"

individuals in each generation. Breeders also want homogeneity; they try to achieve this by systematic inbreeding, which increases homozygosity. However, breeders have long known that inbreeding usually leads to a reduction in fitness, owing to the deterioration in important attributes, such as fertility, vigour and resistance to disease. This is known as *inbreeding depression*

Outbreeding (Cross Breeding)

Johanssen obtain nineteen pure lines of common garden bean (*Phaseolus vulgaris*) with noticeable variations in the size. He selected out the largest, smallest and other grades and planted for the next year. He again noted size of the beans. The largest seeds were from the largest of the past generations and smaller for the smaller. He selected out these variations and planted for next generation, but this time he could not note such segregation. Thus, selection was effective only for one generation and this is because in bean self-fertilization occurs and so they are normally homozygous. If, there was any change in character (size) was purely due to the environmental factors. Johanssen thus, concluded that selection could not produce new character. This made commercial breeders to think out a way of introducing new genes into a population.

Induction of mutations artificially may be taken as a mean of introducing new genes which may change the characteristics of this individual. But appearance of harmful mutations renders this practice nearly unimportant for commercial breeders. Another method of introducing new genes into the population is through outbreeding. It is often possible to outbreed a desirable type to another type less desirable. Then through selection, the degree of desirable characters of the original stock may be of great value to man even if the original main stock might be inferior.

For example, in the Connecticut Valley, a kind of tobacco wrappers, there are two varieties of this tobacco, one is Sumatra and second Broadleaf. The two varieties are different in the size of

leaves. In Sumatra type, the leaf is small with rounded tip while in Broad leaf type the leaf is quite large but tip is pointed. The consumers want to get suitable type with large leaf and rounded tip. By crossing the two, this type of new variety can be obtained. Secondly, this variety is also suitable due to greater number of leaves per plant. This new variety (round tip) is also resistant to disease and with better root system.

Outbreeding for Specific Types

Outbreeding is often done in animals to obtain specific types suited to market purposes. For example, crossing the white short horn and black angus cattle, a blue roan hybrid is obtained. This hybrid is very useful because it produces high quality of beef and for utilization of food. It is also important for its vigour and rapid growth. Dairy cattle are sometime crossed with beef cattle in order to produce calves superior for meat production.

In the central part of Florida, there are often seen huge humpbacked Brahma bulls along with American breed cows. Hybrids of such cattle are valuable for their tolerance of tropical heat. They are also resistant to cattle diseases caused by insects and arthropods. In Australia and South Texas these Brahmas are used extensively for hybridization purposes.

The same principle of outbreeding may be applied within the breed by establishing the two strains of stock by selection and inbreeding, from which, the animals of market value can be obtained after crossing. It can be more clear with the example of poultry, Wyandottes, two strains of which have been developed for cross breeding for the production of eggs. One strain is heterozygous with silver plumage-produced by a dominant sex-linked gene while other strain with gold plumage-produced by homozygous recessive alleles. A cross between these two strains is done and egg-laying pullets are produced. The pullets are easily distinguished just after hatching as female chicks will be gold and males always silver. These pullets possess higher vigour, more resistant to diseases, early maturing and they lay many eggs. Thus, outbreeding is easily applied to take advantage of vigour and it can also be used to produce new breed as well.

Some hybrid varieties in Animals

1. The inbred bulls of here food cattle were crossed with unrelated cows which were sired by other inbred bulls. The hybrids were found to be heavier than the inbreeds (about 12% heavier).
2. Improved varieties of sheep have been developed by crossbreeding Rambovellet variety with Fine short wool and the Linchon with Good meat quality. The hybrid Columbia

- breed had intermediate wool and had good meat quality at the western sheep breeding laboratory.
3. Hybrids have been obtained between black-faced Hampshire sheep and Rambouillets. These have smutty-faced lambs with excellent quality of meat.
 4. One type of Zebu, the Brahaman, representing a geographical race of cattle of India has been crossed with the domestic cattle of European origin. The hybrids are found to exhibit remarkable adaptability to warm, humid climates. Their milk production was increased above that of either parent.
 5. The blue grey cattle in Britian are hybrids produced by a cross between white short horns and Aberdeen Angus.
 6. Cross breeding has been attempted in domestic fowl and game birds.

HYBRID VIGOUR (HETEROSIS)

It is established fact that crossing between different races, varieties or species of animals leads to production of more vigorous hybrids which are, sometimes larger in size too. This fact is known as *hybrid vigour or heterosis*. Very striking example of hybrid vigour is mule. It is produced by crossing horse and she-ass. It is larger than ass and stronger than either of the parents. Only disadvantage of it is that it is sterile so to get a mule, we have to cross the two parents every time afresh.

Hybrid vigour is of many manifestations, some of which can be as follows:

1. Early Maturing Individuals

The hybrids produced are early maturing, thus, shortening the life cycle which is of great advantage in case of cereals, tomatoes etc. This increases the production as harvesting and will come soon after the past generation.

2. More Longevity

The hybrids produced in some stocks, live longer which helps the experiments. For example, hybrids of fruit fly have longer age. *Gaertner* has shown this fact in some hybrid races of plants too.

3. Better Viability

Newman cross-fertilized the eggs of fish *Fundulus heterochitus* with the sperm of *F. majorlis* and raised the hybrid generation which was more viable, more vigorous and fast-growing as compared to pure breed. (But cross between sperm of *Fundulus heterochitus* and eggs of *F. majorlis* showed off springs with less viability). He had also done same cross-breeding experiments with the

eggs of sea-urchin (*Strongylocentrotus purpuratus*) and sperms of *S. franciscanus*, giving the same conclusions.

4. Better Vegetative Propagation

In plants, many hybrids are proved to be great success in the mode of vegetative propagation. Besides maintaining the fortunate combination of genes, vegetative propagation also maintains the hybrid vigour also. Strawberries, Brambles, Grasses etc. are supposed to be hybrids which propagate efficiently by vegetative methods.

Genetic basis of Heterosis

Several hypothesis have been put forward to explain the basis of heterosis. These are:-

1. Overdominance hypothesis: This hypothesis was proposed by SHULL and EAST (1908). The superiority of heterozygote is attributed to the metabolic advantage of the gene products produced by the two different kinds of alleles over the products of only one kind in a homozygous form. Sometimes dominant and recessive homozygotes produce different metabolic substances. Heterozygotes in such cases produce both the substances simultaneously and reap the advantages of the presence of both. Sickle cell heterozygosis (Hb^a/Hb^b) exemplify this situation. Such persons possess normal and sickle haemoglobin, the former preventing hemolytic anaemia and later malarial infection.

2. Dominance hypothesis: It was proposed by JONES (1917) and later elaborated by FISHER, MATHER and many others. According to this theory, the increased vigour and size in a hybrid is due to the combination of favourable dominant genes by crossing two inbreed races. The useful characters are determined dominant alleles. In the absence or in the presence of recessive alleles, the desired characters are lost and vigor decreases. In a crossbreed, if the parents contained different dominant genes, all or most of them are inherited by the hybrid so that the number of dominant genes in a hybrid is more than either of the parents. Most of these characters are quantitative and are controlled by a number of genes. Therefore the phenotypic expression of these characters is the cumulative effect of dominant genes.

General Effects of Inbreeding and Outbreeding

Inbreeding in organisms tends to stabilize the type by bringing homozygosity. As a result of inbreeding, recessive genes become in homozygous condition and express themselves in the off springs. Some of these recessive genes may be deleterious. These genes which express themselves in natural populations are subjected to natural selection and inefficient or defective individuals are

weeded out.

In contrast to inbreeding, outbreeding decreases the constancy by increasing heterozygosity for different characters. This type of mating tends to keep the recessive genes in heterozygous condition. Therefore, recessive genes seldom get a chance to come together and express themselves.

Inbreeding if continued over a long period establishes pure lines, whereas out breeding provides heterozygosity and greater variation for natural selection to work on.

Evolutionary significance of Inbreeding and Out breeding

Both inbreeding and out breeding provides raw material for natural selection. Inbreeding allows the natural selection to operate on recessive genes, which may be eliminated from the gene pool of population by natural selection in due course of time. However, it does not permit the introduction of good germplasm from outside. Out breeding, on the contrary, introduces new genes to the gene pool of the population and provides an opportunity for the accumulation of good or beneficial characteristics from different populations in one individual or in one population. It exposes new combinations of genes to the natural selection to operate and does not allow deleterious genes to express.