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FACULTY OF AGRICULTURAL SCIENCES AND ALLIED INDUSTRIES

Various theories of Heterosis and Inbreeding depression

Inbreeding depression: Cross pollinated species and species reproducing asexually are highly heterozygous. When these species are subjected to selfing or inbreeding they show severe reduction in vigour and fertility. This phenomenon is known as inbreeding depression.

Inbreeding: It is mating between individuals related by descent or having common ancestry. (Brother - Sister mating or sib mating). The highest degree of inbreeding is obtained by selfing.

History of inbreeding: In breeding depression has been recognised by man for a long time. Knowing the consequences of inbreeding many societies have prohibited marriages between closely related individuals. Darwin in 1876 published a book "cross and self fertilization in vegetable kingdom" in which he concluded that progenies obtained from self fertilization was weaker in maize. Detailed and precise information on inbreeding in maize was published by East in 1908 and Shull in 1909.

Effects of inbreeding

1. Appearance of lethal and sub lethal alleles: Chlorophyll deficiency, rootless seedlings and other malformations.
2. Reduction in vigour : Appearance of dwarf plants.
3. Reduction in reproductive ability - Less seed set, sterility
4. Segregation of population in distinct lines.
5. Increase in homozygosity 6. Reduction in yield.

Degrees of inbreeding depression Various plant species exhibit different degrees of inbreeding depression. The depression may be from very high to nil. Based on degree of depression, the plant species can be grouped into 4 broad categories.

1. **High inbreeding depression**

Inbreeding leads to severe depression and exhibit lethal effects. After 3 or 4 generations of selfing it is hard to maintain lines. E.g. Lucerne, Carrot.

2. **Moderate inbreeding depression**

Though lethal effects are there, lines can be separated and maintained. E.g. Maize, Jowar, Bajra.

3. **Low inbreeding depression**

Only a small degree of inbreeding depression is observed. E.g. Cucurbits, Sunflower.

4. **No inbreeding depression**

The self-pollinated crops do not show inbreeding depression.

Heterosis

It is defined as the superiority of F1 hybrid over both the parents in terms of yield or some other characters. The term heterosis was first used by Shull in1914.

Types of heterosis

1. Average heterosis: It is the heterosis where F1 is superior to mid parent value. In other words superior to average of two parents. This type of heterosis is of no use in agriculture since the superiority is below the better parent value.
2. Heterobeltiosis : Superiority of F1 over the better parent.
3. Economic heterosis: Superiority of the F1 compared to the high yielding commercial variety in a particular crop.
4. Negative heterosis: Performance of F1 inferior to better parent / mid parent value. – e.g. Duration

Heterosis or hybrid vigour

Hybrid vigour is used as synonym of heterosis. Hybrid vigour refers to superiority of Fl over better parent. In other words hybrid vigour is manifested effect of heterosis. Thus the term hybrid vigour is used to distinguish the F I superiority from negative heterosis.

Manifestation of heterosis may be in the following forms:

1. Increased yield.
2. Increased reproductive ability.
3. Increase in size and vigour.
4. Better quality
5. Greater adaptability.

Genetic basis of heterosis

There are two main theories of heterosis :

1. Dominant hypothesis
2. Over dominance hypothesis.

1. **Dominant hypothesis** was first proposed by Davenport in 1908. It was later on expanded by Bruce, Keeble and Pellow.According to this hypothesis at each locus the dominant allele has favourable effect, while the recessive allele has unfavourable effect. In heterozygous state, the deleterious effect of recessive alleles are masked by their dominant alleles. Inbreeding depression is produced by the harmful effects of recessive alleles, which become homozygous due to inbreeding.

2. **Over dominance** hypothesis was independently proposed by East and Shull in 1908. It is also known as single gene heterosis or super dominance theory. According to this hypothesis, heterozygotes or atleast some of the loci are superior to both the homozygotes. Thus heterozygote Aa would be superior to AA and aa. In 1936 East proposed that at each locus there are several alleles at a2 a3 &I etc, with increasingly different functions. Heterozygotes between more divergent alleles would be more heterotic E.g. at &I will be superior to aj a2 or a2 a4.

Evidences for over dominance

In maize the maturity genes in heterozygous conditions are superior i.e. Ma ma. The heterozygote Mama is more vigorous than MaMa or mama. The human beings sickle cell anaemia is caused by ss which is lethal. But heterozygote individuals having Ss have advantage of having resistance against malaria compared to SS individuals.

Physiological basis of heterosis

Numerous studies were made to find out the physiological basis of heterosis. Earlier studies were related to embryo size, seed size, growth rates at various stages of development, rates of reproduction. It was suggested that hybrid vigour was resulted from larger embryo and endosperm size of hybrid seeds. This was clearly demonstrated in certain cases only. In 1952 Whaley has concluded that primary heterotic effect is due to growth regulators and enzymes in the F 1. But all these studies were highly speculative. There was no evidence to point out clearly the possible reasons for heterozygote advantage.

Recent studies about heterosis

1. **Reduced amount of single gene product**: In certain cases the heterozygote produces an intermediate amount of a gene product, which may lead to increased vigour and growth rate.

AA - more gene product
aa - Less gene product
Aa - Intermediate gene product.
This is seen in case of bread mold.
Neurospora crassa. Gene Pab+ Produces P. amino benzoic acid. Gene Pab Produces Less P. amino benzoic acid. Heterozygote Pab + Pab - Intermediate amount of P amino benzoic acid which leads to faster growth of the fungus.

2. **Separate gene products**: AA - produce protein, aa - Produce protein which is slightly different, Aa - will have both the Products. This may have many advantages by

having more adaptiveness. Human beings: SS Resistant to sickle cell anaemia ss - Susceptible Ss - Resistant to Sickle cell anaemia + malaria.

3. **Combined gene product:** Otherwise hybrid product. The hybrid may produce an enzyme molecule which may be somewhat different compared to enzymes produced by homozygotes. Such heterozygote enzymes are termed as Hybrid Substance which may be the reason for hybrid vigour.

4. **Effect in two different tissues**: Both homozygotes may produce high levels of an enzyme in two different tissues. But heterozygote may produce intermediate level. E.g. Maize Adh gene for enzyme alcohol dehydrogenase in seeds.