Lecture: - 15

Heterosis

- The term heterosis was first used by Shull in 1914.
- Heterosis:- It may be defined as the superiority of an F, hybrid over both its parents in terms of yield or some other character. Generally, heterosis is manifested as an increase in vigour, size, growth rate, yield or some other characteristic
- Average heterosis or relative heterosis:-The superiority of F, is estimated over the average of the two parents, or the mid parent. If the hybrid is superior to the mid -parent, it is regarded as heterosis.
- Standard/ Commercial Heterosis:- When heterosis is estimated over standard commercial hybrid it is called as standard heterosis.
- Heterobeltiosis:-When heterosis is estimated over the superior parent; such an estimate is sometimes referred to as heterobeltiosis.

15.1 Manifestations of Heterosis:-

- Heterosis is the superiority of a hybrid over its parents. This superiority may be in yield, quality, disease and insect resistance, adaptability, general size or the size of specific parts, growth rate, enzyme activity, etc. These various manifestations of heterosis may be summarised as follows.
- Increased yield:- Heterosis is generally expressed as an increase in the yield of hybrids. The yield may be measured in terms of grain, fruit, seed, leaf, tubers or the whole plant.
- Increased Reproductive ability:- The hybrids exhibiting heterosis show an increase in fertility or reproductive ability. This is often expressed as higher yield of seeds or fruits or other propagules, e.g., tuber in potato (S. tuberosum), stem in sugarcane (S. officinarum), etc.
- Increase in Size and General Vigour: The hybrids are generally more vigorous, i.e., healthier and faster growing and larger in size than their parents. Some examples of increased size are increases in fruit size in tomato, head size in cabbage, cob size in maize, head size in jowar, etc.

- Better Quality:-In many cases, hybrids show improved quality. This may or may not be accompanied by higher yields. For example, many hybrids in onion show better keeping quality, but not yield, than open-pollinated varieties.
- Earlier Flowering and Maturity:- In many cases, hybrids are earlier in flowering and maturity than the parents. Earliness is highly desirable in many situations, particularly in vegetables. Many tomato hybrids are earlier than their parents.
- Greater Resistance to Diseases and Pests:- Some hybrids are known to exhibit a greater resistance to insects or diseases than their parents.
- Greater Adaptability:- Hybrids are generally more adapted to environmental changes than inbreds. In general, the variance of hybrids is significantly smaller than that of inbreds. This shows that hybrids are more adapted to environmental variations than are inbreds. In fact, it is one of the physiological explanations offered for heterosis.
- Faster Growth Rate:-In some cases, hybrids show a faster growth rate than their parents. But the total plant size of the hybrids may be comparable to that of parents. In such cases, a faster growth rate is not associated with a larger size.
- Increase in the Number of Plant Part:- In some cases, there is an increase in the number of nodes, leaves and other plant parts, but the total plant size may not be larger. Such hybrids are known in beans (P. vulgaris) and some other crops.

15.2 Prediction of the Performance of Double Cross Hybrids:

- In a double cross hybrid, four inbred parents are involved. Theoretically, the potential of the double cross will be the function of the inbreeding value of these four parental inbreds. Therefore, based on the procedure of testing of the breeding value of inbreds, the performance of a double cross hybrid can be predicted through any of the four methods indicated by Jenkins (1934). Starting with the simplest procedure these methods are:
- Top-cross testing (one cross per inbred) to know the breeding value to each of the four inbreds (total 4 top-crosses per double cross).
- Mean of the four non-parental single crosses involved in (AXB) X (CXD) double cross, viz., (AXC), (AXD), (BXC) and (BXD) (total 4 non-parental single crosses per double cross).

- Average yield performance of all possible six crosses [n(n-1)/2], namely AXB, AXC, AXD, BXC, BXD and CXD (total six crosses per double cross).
- Average progeny-performance of each inbred can be de termined by the mean performance of each inbred in all possible single crosses where it occurs (n-1 crosses per inbred). For instance, the mean performance of AXB, AXC and AXD will determine the average breeding value of the inbred A. Similarly, the mean of AXB, BXC and BXD will indicate the potential of the inbred B and so on (total 12 crosses per double cross).

15.3 Genetical Basis of Heterosis:- The genetical basis of heterosis follows two hypotheses:

A. Dominance hypothesis of heterosis. B. Over dominance hypothesis of heterosis.

Dominance hypothesis:-

- The hypothesis, first proposed in 1908 by Davenport and later in 1910 supported independently by Bruce and by Keeble and Pellew.
- Heterosis due to superiority of dominant alleles over recessive alleles. heterosis is directly proportional to the number of dominant genes contributed by each parent.
- > AABBccdd x aabbCCDDAaBbCcDd hybrid with 4 dominant genes

Parent 1	⇒	Parent 2	

With 2 dominant genes With 2 dominant genes

- > Heterosis is not due to heterozygocity *per se*.
- Superiority of dominant alleles over recessive alleles.
- ▶ Heterosis is due to masking of deleterious recessive alleles by dominant alleles.
- Heterosis is directly proportional to the number of dominant genes contributed by each parent.

Genetic Basis of Heterosis dominance hypothesis:-

Explanations:-

- Dominance of linked gene hypothesis (Jones, 1917).
- Smooth and symmetrical as yield is governed by polygene's (Collins, 1921).

Objections:-

- True breeding homozygous individuals for all dominant genes in F_{2.}
- F₂ Curve should be skewed towards dominant gene.

Over dominance hypothesis:-

- > This hypothesis was proposed in 1908 by Shull and East, independently.
- It is assumed here that there is a physiological stimulus to development that increases with the diversity of the uniting gametes. In other words, using Mendelian terms, it means that there are loci at which the heterozygote is superior to either homozygote and that vigour increases in proportion to the amount of heterozygosity.
- Various workers have given different names to this hypothesis such as 'single-gene heterosis','cumulative action of divergen alleles' and 'stimulations of divergent alleles'. Fisher (1930) called it superdominance.

Genetic Basis of Over-dominance Hypothesis:-

- Heterozygosity per se is the cause of Heterosis
- Heterozygote is superior to better parent.
- Increase in vigour is directly proportional to diversity of combining alleles.
- Superiority of heterozygote may arise due:
 - a) Production of superior hybrid substance in heterozygote
 - b) Cumulative action of divergent alleles
- More divergent alleles will exhibit more heterosis than less divergent ones.

Evidence:-

• They are not many clear cut cases where the heterozygote is superior to the two homozygote ; in fact over dominance has not been demonstrated unequivocally for any polygomic trait: in case in maize gene ma affects maturity. The heterozygote's Ma ma is more vigorous and later in anthesis and maturity than the homozygote's Ma Ma.

Objections:-

- Evidences of single locus heterosis may not hold good for quantitative characters like yield.
- Quantitative estimation of over dominance is difficult due to linkage basis.

Epistasis Hypothesis:-

- In 1952, Gowen had suggested that influence of one locus on the expression of another may be involved in heterosis. Subsequently, considerable data has accumulated to implicate epistasis as a cause of heterosis. For example, a majority of heterotic crosses show significant epistasis. But all heterotic crosses do not show epistasis, and all crosses that show epistasis are not heterotic.
- In many cases, the effects of a single homozygous successive allele is epistatic to almost the whole genetic makeup of an inbred. When the effects of such an allele are masked by its dominant allele, the effects on heterosis are usually dramatic (Stuber 1994).

INBREEDING DEPRESSION

Inbreeding Depression: - It may be defined as the reduction or loss in vigour and fertility as a result of inbreeding.

Inbreeding depression = $F1-F2 / F1 \times 100$

- The chief effect of inbreeding is an increase in homozygosity in the progeny, which is proportionate to the degree of inbreeding.
- > The degree of inbreeding of an individual is expressed as inbreeding coefficient (F).
- > The degree inbreeding is proportional to degree of homozygosity.
- East (1908) and Shull (1909) independently showed the effect of inbreeding depression while working in maize. Subsequently scientists reported inbreeding depression in other crop plants.

Effects of Inbreeding depression:-

- Inbreeding is accompanied with a reduction in vigour and reproductive capacity i.e. fertility.
- Appearance of Lethal and Sublethal Alleles : IB results in appearance of lethal; sublethal and subvital characters. Eg : Chlorophyll deficiencies, rootless seedlings, flower deformities.
- Reduction in vigour : General reduction in vigour size of various plant parts.
- **Reduction in Reproductive ability** : Reproductive ability of population decreases rapidly. Many lines reproduce purely that they can not be maintained.
- Separation of the population into distinct lines : population rapidly separates into distinct lines i.e. due to increase in homozygosity. This leads to random fixation of alleles in different lines. Therefore lines differ in genotype and phenotype. It leads to increase in the variance of the population.
- Increase in homozygosity : Each lines becomes homozygous. Therefore, variation within a line decreases rapidly. After 7-8 generations of selfing the line becomes more than 99% homozygous. These are the inbreds. These have to be maintained by selfing.
- **Reduction in yield :**IB leads to loss in yield. The inbreds that survive and maintained have much less yield than the open pollinated variety from which they have been developed.