

Lecture: - 12

HARDY WEINBERG LAW – FACTORS AFFECTING EQUILIBRIUM FREQUENCIES IN RANDOM MATING POPULATIONS

- According to Hardy (England,1908) and Weinberg (Germany,1909), gene and genotype frequency of a Mendelian population remain constant generation after generation unless there is selection,mutation,migration or random drift.
- Suppose in a population of plant species, a gene has two allele, 'A' n 'a' having frequency 'p' n 'q' respectively.
- The frequencies of their genotypes AA, 2Aa and aa are p, 2pq and q.
- Acc. to this law, the frequency of p and q in a population remains constant generation after generation unless there's any factor's influence.
- Validity of Hardy-Weinberg law: Random union of gametes
 Female gamete Male gamete A(p)
 a(q) A(p) AA(p²) Aa(pq) a(q) Aa(pq) aa(q²)
 Genotype frequency AA:2Aa:aa p²:2pq:q².
- Frequency of A and a from AA,2Aa and aa individuals - p²+2pq+q² = (p+q)= 1 {since p+q=1}
- Frequency of 'A' gametes from AA and Aa individuals - p² +1/2 2pq = p(p+q) = p
- Frequency of 'a' gametes from Aa and aa individuals - q² +1/2 2pq = q(q+p) = q {since q+p is p+q and p+q=1} Suppose Genotype frequency AA (p²) Aa (2pq) Aa (q²).

| Female gamete | Male gamete | | |
|--------------------|-------------|--|--------|
| | | A(p) | a(q) |
| | A(p) | AA(p ²) | Aa(pq) |
| a(q) | Aa(pq) | aa(q ²) | |
| Genotype frequency | | AA: 2Aa :aa p ² : 2pq : q ² | |

Random union of gametes

Random mating of genotypes:-

| Mating | Probability | Frequency of Progeny | | |
|---------|--------------------------------|-------------------------------|--------------------------------|-------------------------------|
| | | AA | Aa | aa |
| AAxAA | p ⁴ | p ⁴ | - | - |
| AA x Aa | 4p ³ q | 2p ³ q | 2p ³ q | - |
| Aa x aa | 2p ² q ² | - | 2p ² q ² | - |
| Aa x Aa | 4p ² q ² | p ² q ² | 2p ² q ² | p ² q ² |
| Aa x aa | 4pq ³ | - | 2pq ³ | 2pq ³ |
| Aa x aa | q ⁴ | - | - | q ⁴ |

- Frequency of AA progeny will be- $p^4 + 2p^3q + p^2q^2 = p^2(6p^2 + 2pq + p^2) = p^2(p+q)^2 = p^2$ { since $(p+q)=1$ }
- Frequency of aa progeny will be - $p^2q^2 + 2pq^3 + q^4 = q^2(p^2 + 2pq + q^2) = q^2(p+q)^2 = q^2$ { since $(p+q)=1$ }
- Frequency of Aa progeny will be - $2p^3q + 2p^2q^2 + 2p^2q^2 + 2pq^3 = 2p^3q^2 + 4p^2q^2 + 2pq^3 = 2pq(p^2 + 2pq + q^2) = 2pq$

12.1 Factors affecting equilibrium frequencies:

The equilibrium in random mating populations is disturbed by (1) migrations, (2) mutation, (3) selection and (4) random drift. These factors are also referred to as evolutionary forces since they bring about changes in gene frequencies, which is essential for evolution to proceed. Obviously, a population in which gene and genotype frequencies remain constant over generations cannot evolve any further, unless its gene and genotype frequencies are disturbed.

12.1.1 Migration:-

Migration is the movement of individuals into a population from a different population. Migration may introduce new alleles into the population or may change the frequencies of existing alleles. The amount of change in gene frequency q will primarily depend upon two factors ; first, the ratio of migrant individuals to those of the original population and second, the magnitude of difference between the values of q in the population and in the migrants. In plant breeding programmes, migration is represented by intervarietal crosses, polycrosses, etc., wherein the breeder brings together into a single population two or more separate populations.

12.1.2 Mutation:-

Mutation is a sudden and heritable change in an organism and is generally due to a structural change in a gene. It is the ultimate source of all the variation present in biological materials. Mutation may produce a new allele not present in the population or may change the frequencies of existing alleles. However, since the mutation rate is generally very low, i.e., approximately 10^{-6} , the effects of mutation on gene frequency would be detectable only after a large number of generations. Therefore, in breeding populations such effects may be ignored. A desirable mutation may prove very useful when it is discovered. But a routine use of mutations in crop improvement would not be feasible until techniques for directed mutagenesis have been perfected. Directed mutagenesis implies that the experimenter should be able to induce a high

frequency of the desired mutations through certain techniques. At present, directed mutagenesis is an ideal, which is yet to be achieved even partially.

12.1.3 Random drift:-

Random drift or genetic drift is a random change in gene frequency due to sampling error. Random drift occurs in small populations because sampling error is greater in a smaller population than in a larger one. Ultimately, the frequency of one of the alleles becomes zero and that of the other allele becomes one. The allele with the frequency of one is said to be fixed in the population because there would be no further change in its frequency. It may be expected that in a small population all the genes would become homozygous, or would be fixed in due course of time. Breeding populations are generally small, hence a certain amount of genetic drift is bound to occur in them. The breeder cannot do anything to prevent this genetic drift, except to use very large populations, which is often not practicable. Alternatively, he may resort to phenotypic disassortative mating, which would again require time, labour and money.

12.1.4 Inbreeding:-

Mating between individuals sharing a common parent in their ancestry is known as inbreeding. In small populations, a certain amount of inbreeding is bound to occur. Inbreeding reduces the proportion of heterozygotes or heterozygosity and increases the frequency of homozygotes or homozygosity. The rate of decrease in heterozygosity is equal to $\frac{1}{2N}$ (N =number of plants in the population) per generation in monoecious or hermaphrodite species. In dioecious species and in monoecious species where self-pollination is prevented, the decrease in heterozygosity is somewhat lower; it is equal to $\frac{1}{2(N+1)}$ per generation. Thus in small populations, even with strict random mating or even with strict cross-pollination the frequency of homozygotes increases, while that of heterozygotes decreases due to inbreeding.

12.1.5 Selection:-

Differential reproduction rates of various genotypes is known as selection. In crop improvement, selection is very important because it allows the selected genotypes to reproduce, while the undesirable genotypes are eliminated. Thus the breeder is able to improve the various characteristics by selecting for the desirable types. In a random mating population, if plants with AA or aa genotypes are selected, the frequency of A allele in the selected population would be 1 or 0, respectively. It is assumed in this case that AA and aa genotypes would be identified

without error. In the next generation, therefore, only A or a allele would be present, i.e., the alleles would be fixed. Here selection against the remaining genotypes is complete, that is, these genotypes are not allowed to reproduce. In such cases, the disadvantage in reproduction, i.e, selection differential ($=s$) is 1 and the fitness is zero for the remaining genotypes. The fitness of a genotype may be defined as its reproduction rate in relation to that of other genotypes. Generally, s has values less than one. Further, often it is not possible to identify the genotypes with certainty. The identification of genotypes is made difficult by dominance and due to less than 100 per cent heritability. This is particularly true for quantitative characters. As a result, selection is expected to change gene frequencies rather than to eliminate one or the other allele.