Course Name: Basics of Crop Breeding and Plant Biotechnology

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Week: 04

Lecture -18: Population Genetics (Part - I)

Hello everybody. Welcome to the Basics of Crop Breeding and Plant Biotechnology course. Under module 2 i.e. Principles of Conventional Plant Breeding, today we will discuss, i.e. on population genetics. So, these are the concepts which will be covered under this particular part. First one, we will discuss about the genetic composition of cross-pollinated crops. Next we will discuss, about the Hardy-Weinberg law that is associated with the population genetic study in cross-pollinated species.

Next we will discuss about the different assumptions of Hardy-Weinberg equilibrium to maintain the Hardy-Weinberg equilibrium, what are the things we need to consider? Then we will discuss, about some specific definitions like what is gene frequency, what is genotype frequency in a population? Then the frequency determination of allele in a Hardy-Weinberg population will be discussed. Then we will discuss about the random union of gametes within a population which is in Hardy-Weinberg equilibrium.

Next we will discuss, about the random mating of individuals, if different individuals mate randomly then, what will be the constitution genetic constitution in next generation? Then we will discuss different factors affecting, the equilibrium in Hardy-Weinberg population and finally, we will discuss about some numerical problems associated with Hardy-Weinberg equilibrium. So, let us start with the genetic composition of a cross-pollinated population. First of all, it is known to us that the cross-pollinated crops are highly heterozygous, due to free intermating among individuals. Ok! Suppose if different plants are available, cross-pollinated crops in a particular field, any one of them can, the pollen grains of any of this particular plant can fertilize another one and similarly in this way, the heterozygous condition is maintained in the population, right, and the cross-pollinated species they have heterozygous balance also.

So, they are highly heterozygous in nature, if free inter-mating is taken place. Next one, in random mating population, each plant has equal opportunity of mating with any other individual of the population. What I was telling anyone of this plant can mate with another one within the population. So, it is known as random mating population, ok, no selected advantage is there, not a few plants are selected from there before mating, and it is also known as panmictic population or Mendelian population. Next a gene pool, this concept will be coming in this Hardy-Weinberg equilibrium again and again.

So, what is gene pool? Gene pool is the sum total of all the genes present in the population, it is the sum total of all the genes present in the population. It is during this Hardy-Weinberg equilibrium, we should not consider is about a single gene means, how a single gene is transmitted means, total gene pool is transmitted... a large number of genes are transmitted. Within that we can calculate the frequency of a particular allele of a gene, we will discuss, we will be discussing later on, but the gene pool concept is very much available over there. Next one a Mendelian population, may be thought of having a gene pool consisting of all the gametes produced by the population. So, basically, within the gene pool all the gametes of different genes will be available, all the gametes producing from different parents will be available, not from different genes all the gametes producing from all the different plants will be available over there, because each male gamete can fertilize each and every female gametes over there.

So, it is random mating in nature. Next, we are coming to the Hardy-Weinberg law. First of all, it is the fundamental law of population genetics, and provides the basis for studying Mendelian population. I was discussing earlier because the random mating population is also known as panmictic population or Mendelian population. Now what is that Mendelian population, is that a group of sexually interbreeding organisms living within a circumscribed area means, within a particular area. Ok!

It should not be too much small, but within a specific area suppose a plant which is growing in West Bengal, cannot do cross-pollination with a plant which is growing in Bihar or Orissa region, right? So, they should be in close proximity and within a circumscribed area, and they can do interbreeding among themselves. So, that is the Mendelian population. Now coming to the law, what is the Hardy-Weinberg law? The law states that, the gene and genotype frequencies in a Mendelian population remain constant generation after generation. The gene frequency and the genotype frequencies both of these remain constant generation after generation in a Mendelian population.

If there is no selection, no mutation, no migration or no random drift or genetic drift. Ok! So, if these things are not available, then the gene frequency and the genotype frequencies will remain constant generation after generation i.e. the basis of Hardy-Weinberg law. Now, this law was proposed by mathematician H. Hardy and German physician Winberg independently, they independently gave this particular law, Hardy gave it in 1908 and Winberg gave it in 1909, respectively. And it describes populations that are not evolving means, no natural selection is being done, sorry, no human based selection is being done means, if we consider about pure line selection.

In pureline selection we were considering some of the better plants from the population. In mass selection we are identifying some of the plants based on phenotype, but over here naturally they will intermate it is not evolving. So, let us discuss about different assumptions, of Hardy-Weinberg equilibrium or Hardy-Weinberg population. First of all, this we assume that the population will be maintained in Hardy-Weinberg equilibrium if the individuals are deployed in nature, ok, if the individuals are having two sets of chromosomes that is deployed in nature. Then only sexual reproduction occurs, sexual reproduction means in case of a sexually reproduced population, this Hardy-Weinberg equilibrium will not be maintained because they have to intermate randomly, right?

So, sexual reproduction is needed in those crops. Next population must be large, if the population size is small then our selection will be also not up to the mark, and maybe some of the favorable alleles could be selected. So, the population must be large, so that the error will be minimized during harvesting of certain plants, so that it will be grown in the next generation, that frequency, the error percentage could be increased if the population becomes small. Next one, no immigration or emigration means, none of the plants from this population will be moving outside or new alleles from other population will not come over here. The no mutation means we will assume that no mutation is occurring.

So, that suppose, this allele was available and it is another allele for this gene is small a, capital A and small a are two different alleles of a gene. So, we should assume that no other new alleles are being formed during this equilibrium process. Next one, natural selection here manmade selection is not practiced. So, natural selection is done, if any plants cannot sustain it will be killed eventually, and whatever will be available naturally based on that we need to harvest it and in next generation we can calculate the frequency. And random mating that is true in case of Hardy-Weinberg, but equilibrium, the population has to mate randomly means, each and every individual plants can be fertilized with another one plant available in this population.

Now, we will be discussing about the gene frequency and genotype frequency. Now, what is gene frequency? These things will be coming in this particular chapter again and again. Gene frequency is the frequency of different alleles, frequency of different alleles of a particular gene in a population, that is gene frequency. Ok! Since I am telling that frequency of different alleles, of a particular gene suppose A gene, it has two different alleles capital A and small a. So, what will be the frequency of capital A? What will be the frequency of small a? Those are the gene frequencies means, frequency of different alleles of a population.

Now, if this gene has three different alleles B_1, B_2 and B_3 suppose, B gene has three different alleles, then frequencies of this allele, this allele and this allele, this will be the gene frequencies. Ok! Now, coming to the genotype frequency. Genotype frequency is the frequency of different genotypes of a particular gene. The frequency of different genotypes of a particular gene in a population. Suppose, for A gene if the scenario is like this for A gene how many genotypes will be there? Capital A capital A, capital A small a and small a small a, these three genotypes will be there.

So, the frequency of capital A capital A, frequency of capital A small a and frequency of small a small a. This will be the part of genotype frequency or genotypic frequency. The frequency of different genotypes of a particular gene in a population. So, these things will be coming again and again, in this particular chapter. So, I have discussed it once again.

Now, let us try to determine, the frequency of an allele in a population means, that is we are trying to determine the gene frequency. The frequency of a particular allele of a gene, that is gene frequency. So, we are trying to determine the frequency of an allele, in a population. Let us assume, that in a particular field, different plants are being grown. Suppose 100 plants are there, 100 plants are being grown, and it is an open pollinated population, each plants can be crossed with another one naturally.

We are trying to find out means, out of this, within this 100 plants suppose, tall plants having capital T capital T genotype, tall plants having capital T capital T genotype is 60 tall plants are there, having genotype capital T capital T. While, in the same field tall plants which are heterozygous in nature, for T gene suppose 2 alleles are there, capital T and small t capital T is dominant and small t is recessive in nature. Ok! So, the tall plants in this particular field which is heterozygous in nature, let us assume, it is 30 number of capital T small t plants are available out of these 100 plants. And dwarf plants small t small t, because small t is the recessive allele it is in homozygous condition will be dwarf plant. Ok!

Suppose, its number is 10. So, we had 60 number of tall plants, having genotype capital T capital T, we had 30 number of tall plants having genotype of capital T small t, and 10 number of plants having genotype small t small t. Now, we are trying to determine the frequency of an allele in the population, we are trying to determine the frequency of capital T or frequency of small t allele, within this random mating population. Ok! So, 2 procedures are there, according to 1 procedure first procedure. So, according to first procedure we will try to find out for this gene, for T genes how many capital T alleles are available within the population. Ok! So, how many capital T alleles are available there? So, number of capital T allele, in capital T capital T plants. Ok!

How many number of capital T allele will be there, in this capital T capital T plant homozygous dominant plant it will be 60 X 2, because 60 plants are there, each are in diploid condition, ok, each are having 2 capital T allele. Now number of capital T allele in capital T small t plants, ok, how many capital T small t plants were there 30. So, in these 30 plants which were capital T small t in nature 2 types of alleles will be produced capital T and small t. So, 1 capital T will be produced from all of them. So, let us assume this number is 30, earlier it was 120.

So, total number of capital T allele in the population 120 + 30 = 150 alleles, will be there. Ok! We are assuming that from this capital T capital T, 2 different alleles are being separated during gamete formation. While from the capital T small t, 1 capital T and 1 small t, these 2 alleles are being separated. Ok! So, based on that we have calculated the total number of alleles in the population capital T allele. Now, what will be the frequency? The frequency of capital T allele how can I calculate? It will be the total number of capital T in the population and total number of allele available in the population, right?

Now total number of capital T in the population it was 150, and what is the total number of alleles in the population? We had 100 plants right, each of the plants is having 2 alleles they are in diploid condition. So, it will be 150/200. So, it will be 7.5/10 means 0.75 that will be the frequency. Now let us try to calculate the frequency of small t allele, frequency of small t allele. So, what will be the frequency of small t in the population frequency of small t will be, I am just calculating over here frequency of small t in the population. What it will be? It will be from this plant from this dwarf plant 2 alleles will be produced means 2 X 10 = 20 while, from this plant only 1 allele will be produced means it will be 30 means, total 50 will be there, right, means it will be 50/200 means 2.5/10 that is 0.25. Ok! So, in this way we can calculate the frequencies of 2 different alleles of a particular gene in a population, in a random mating population. So, let us discuss about second procedure. Another procedure is also there, through which we can calculate the frequency of a particular allele. So, according to this procedure so, we are assuming that each of this plant our conditions are same capital T capital T plants are 60, capital T small t plants are 30, and small t small t plants are 10. Ok! Here, from we are assuming that each of the plants is making 1 gamete here, we are calculating number of gametes being produced each of this plant is producing 1 gamete.

So, in a random mating population each gamete can be fused with another, 1 gamete that is known to us. So, number of gametes from capital T capital T plants 60 gametes will be there, right? So, out of those 60 gametes all will be having capital T allele while, number of gametes produced from the heterozygote, 1 total 30 gametes will be there. So, out of these 30, half will be capital T and half will be small t, right, where, the number of gametes from small t small t individuals that will be 10 and all will be small t in nature, right? Now, let us calculate the number of gametes being produced for capital T number of gamete having capital T allele.

So, number of gametes having capital T allele, it will be from here 60, that will be coming from here, plus half of 30 right capital T will be available in the gamete means, half of 30 it means, 60 + 15 that is 75. While, number of gametes having small t allele, having small t allele, it will be 10 + 1/2 X 30 that is 10 +15 = 25, right? Now, let us calculate the frequency of capital T frequency of capital T allele will be there means, number of gametes having capital T allele is the frequency of capital T allele. Ok! It will be 75 divided by total number of gametes produced in the plant total number of gametes in the population, right? So, it will be, what will be the total number of gametes we had initially, 100 plants and we are assuming that each plant is producing 1 gamete.

So, it will be 75/100 means 0.75. Similarly, the frequency of small t will be 25/ (total number of gametes) i.e. 100 = 0.25. So, in this way we can calculate the frequency of an allele in a population, that is the gene frequency could be calculated through this approach. Next, we will be discussing about the random union of gametes. So, earlier we have told that 2 types of gametes will be there means, capital A and small a suppose, 2 types of gametes are there or capital T small t for a particular gene. Ok!

Now we are talking about the random union of gametes. Suppose, in a population we have 2 different alleles of a particular gene, and the frequency of capital A is p, p is the frequency, suppose it is 0.6, 0.6, while the frequency of small a is q. Ok! Suppose, the frequency of capital A allele is p and the frequency of small a allele is q.

Now, according to Hardy-Weinberg equilibrium the population has to be in random mating condition, right? So, let us see if random mating is taken place, capital A and small a both type of gametes will be produced, both type of male gametes as well as both type of female gametes will be produced, they will intermate among themselves. So, what will be the population structure? So, capital A and small a suppose, we are making the checker board. Ok! 2 types of male gametes are there, capital A and small a its frequency is p its frequency is q while, 2 types of female gametes will be there in the population capital A and small a right its frequency is p its frequency is q.

Now, random fusion is being taken place. So, if these 2 fuses together will be having capital A capital A and its frequency will be p^2. If these 2 fuse together will be getting capital A small a and its frequency will be 'pq'. If capital A small a fuse again, its frequency will be 'pq' and once this small a male and small a female gamete will fuse together, will be having small a small a individual its frequency will be q^2. So, initially our gene frequency was $p + q = 1$, and what is our genotype frequency we are getting over here? We are getting genotypic frequency $p^2 + pq + pq + q^2$, i.e. $p^2 + 2\,pq + q^2$, right? It is equals to $(p + q)^2$, we know that $(p + q = 1)$, it means $(p + q)^2 = 1$.

So, that is the Hardy-Weinberg equilibrium this frequency, the gene frequency and genotype frequency will remain constant, generation after generation, until and unless there is no selection mutation, migration or genetic drift.