Course Name: Basics of Crop Breeding and Plant Biotechnology

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Lecture-20: Population Genetics (Part - III)

Welcome back, so we will continue again. Now, we will be discussing about different factors affecting the equilibrium in the population. So, first of all we will discuss about migration. Ok! Migration in plant breeding is analogous to the movement of individuals between populations is represented by inter-varietal cross and poly-crosses. Ok! So, in a particular field we are assuming, that a random mating is supposed to be taken place, a corn field, is there, there random mating is supposed to be made. Ok! Now, maybe a couple of blocks away another field is also there, ok, another maize variety is being grown. Ok!

So, some pollen grains can come from here, if heavy wind blows over there, if proper protection is not taken in this particular boundary region, then some pollen grains can come from here also. So, in this way it is analogous to the movement of individuals between population, and it is represented by inter-varietal cross. Suppose, one variety was being grown over here, another variety its pollen grains could be coming, and maybe pollen grains could be coming from some other field also. So, in this way poly-cross could be also occurred.

So, it will hamper the equilibrium of the Hardy-Weinberg population. Next one, this involves bringing together individuals from distinct populations into a single breeding population. Ok! This involves bringing together individuals from distinct population into a single breeding population. Next one, is we have collected the seeds of maize from different regions from Punjab, Haryana, Uttar Pradesh and certain parts of Rajasthan or Madhya Pradesh we have collected seeds from there, and we have pooled it. Ok! And it is being grown in a particular area, the seeds, if the seeds are mixed then the Hardy-Weinberg equilibrium will not be maintained, because from distinct population different sets of alleles could come, right? new alleles could be available.

So, if we assume that the Hardy-Weinberg equilibrium was being maintained under each of this condition in Punjab, a particular field Hardy-Weinberg equilibrium was being maintained, in Rajasthan in a field the Hardy-Weinberg equilibrium is being maintained. But once those seeds are taken together, then the frequency will be altered because the frequency of different alleles might be changed, or new alleles might be there also. Next, we will discuss about the mutation, ok! that mutation is sudden heritable change in an organism trait, in an organism at its genetic level, at its DNA level and it is usually, caused by a structural alteration in the associated gene. Basically, the sequence of nucleotide in the DNA is changed through it, right, and basically, mutation we can tell it as the ultimate source of any variations, because whatever, the alleles are developed those are mostly developed through mutation. So, mutation is the major reason for developing different alleles of each and every gene. Ok!

And so mutation is one of the important things that is responsible for genetic diversity, that creates variation within the biological materials. But if through this type of mutation suppose, a population is being maintained, ok! here capital A and small a alleles were available, its frequency was small p, its frequency was small q in the population, its random mating population. Now, due to sudden mutation another allele has been formed a_1' suppose, another allele has been formed, how it may form? So, just assume it was the gene sequence, ok! here start codon was ATG, and different sequences were available, this one was allele A. Earlier in the population only two alleles were there, small a allele was there, here this sequence was TTG and this. So, this one was able to produce the protein, and this one was unable to produce protein due to missing or due to mutation in the start codon. Ok!

Now, we are telling that another new allele has been formed ok! it starts with ATG and here some, over here the mutation has been taken place. So, here we may get a protein, but that is different protein, a different protein is being produced by this particular allele. So, in this way earlier we had the scenario of capital A and small a only in the population, right? Now, if new alleles are developed due to mutation then, definitely the overall frequency will be changed because random mating in next generation, this allele could move, could move to other different plants it can make its progeny ok! means it will be transmitted to the progeny. So, in this way total equilibrium will be hampered.

Now, we will be discussing about random drift. So, random drift is a stochastic shift in gene frequencies caused by sampling error. So, earlier we were discussing that our sample size should be optimum. Ok! So, that the sampling error could be minimized. So, it becomes that is random drift it becomes more significant in smaller population, where the impact of chances fluctuations, is the impact of fluctuations is greater compared to larger population with a lower susceptibility to sampling error. Ok!

If the population size is small suppose, this is our plot size and this is another plot size. Let us assume, over here if the population size is like this ok! here suppose we are providing irrigation from here, we are providing irrigation from here. Ok! So, here these plants are growing properly, and these plants are not growing at all. So, only alleles will be coming from these plants because, these plants may be show inferior performance although, we are not going to select once as they are not surviving. So, eventually its allelic frequency will be minimized, will be reduced, but over here if the population size is large then, suppose at this end at this side some of the plants are being killed, but here we can get the pollen grains or we can get the egg cells from most of the plants means, we can get the genetic combinations from most of the plants.

So, in this way over here our sampling error will be more, we may be more choosy. Ok! So, that may cause the random drift of a population. The ultimate outcome of random drift, is the fixation of one allele in the population ok, where its frequency becomes 1 means, like here. If these alleles are almost killed means, the plants which is, which is may be sensitive to this type of lack of irrigation stress those plants will be killed. So, its progeny means, its frequency will be minimized, the alleles responsible for that trait, its frequency will be minimized in the population and ultimately, the favorable allele its frequency becomes 1 because, normally we know that p + q = 1 i.e. the frequency of both the alleles is 1, but if our selection is like this, then the favorable alleles frequency become 1 while the frequency of the unfavorable allele becomes 0.

So, in this way the overall Hardy-Weinberg population dynamics could be changed. Now we will be discussing about inbreeding. We know that inbreeding is the mating between individuals which share a common ancestor, typically involving close relatives; means mating between individuals which are related by descent or ancestry which are somehow related. Ok! Maybe one parent was common, maybe two parents were common. So, if mating is made between them that is inbreeding. Ok!

And in small populations the occurrence of inbreeding is more likely due to limited number of potential mates. So, let us assume we have two different populations right! Here suppose, this plant, this plant, this plant, this plant, these four plants are coming from a particular female. Ok! While other than these 4, another, other than these 4 another 96 plants are available means total, 100 plants are there out of this, these 4 plants are having same parentage means, they are coming from a particular female. While, we have another smaller population there also these 4 plants are there, their female parent was same and here other 6 plants are available.

So, if you just try to correlate these things in small populations, the occurrence of inbreeding is more likely, due to limited number of potential mates means, here number of potential mates out of these 4, other 6 plants are there means total 10 plants were there, right.? So, here chances of inbreeding will be more while, over here 100 plants are available. So, here chances of inbreeding will be less because, from these 96 plants the pollen grains come, come, can come over here, right? So, in this way, in this way, the, if the population size is small the chances of inbreeding will be more because, it is true in the cross-pollinated crops the Hardy-Weinberg equilibrium. Ok! Now the effects of inbreeding include a higher expression of recessive genetic disorder, i.e. known to us means, in case of cross-pollinated species, the, there in the cross-pollinated species the genetic load is high the genetic load, right?

Genetic load means the sum total of the deleterious genes, deleterious alleles available in the cross-pollinated species. In the cross-pollinated species the genetic load is high. So, if inbreeding is taken place, then those recessive alleles will be in homozygous conditions, and we may see different genetic disorders, different reduction in yield, reduction in overall genetic diversity those things could be observed. Ok! Now we will discuss about selection procedure. First of all, selection is the differential reproduction rates of different genotypes means, naturally we will do selection within a field not naturally by ourselves.

Suppose we are doing selection in a particular field ok, here all this plants are being grown initially, what is done in the Hardy-Weinberg equilibrium, each one of them can mate anyone of the another plant available in this population and thereafter, we have to harvest the total produce we have to harvest the seeds there, from a sample will be grown in next year. So, the population will be maintained. Now suppose, we have selected these plants, or we have selected these plants, these two plants have been selected or this plant, these three plants have been selected based on morphology or something else. In next generation we are just pooling the seeds of these three together. So, in earlier one we are just pooling the total seed, and we were making a sample, but over here we have collected the seeds of these three plants only.

So, definitely its progeny will be more means, the chances of inbreeding will be more, because the plants, the seeds produced over here, they will be having one parent common. The seeds produced from here they will be having one parent common. So, in this way, in next generation if selection is done. So, only their seeds will be grown means, differential reproduction rate is being followed, its seeds are not considered eventually, will increase the inbreeding, will be increasing the inbreeding also. So, it is a key factor disturbing the equilibrium in the population.

So, selection should be avoided in random mating population in Hardy-Weinberg population. Next one, in a random mating population selection can significantly alter the frequency of alleles, but is generally unable to fix or eliminate them completely. In a random mating population suppose, we are doing selection because they are most of the individuals are in heterozygous condition, it is the random mating, it is in cross-pollinated condition most of the things are in heterozygous condition. So, maybe we can select this one and this one. Ok! So, our frequency of small a will be less right, if only these two are selected, its frequency will be lesser, but the thing is that, it will not be eliminated, the complete elimination will not be available right, because some of the individuals will be having the small a as the population structure is mostly in heterozygous condition. Ok!

However, when combined with a system of inbreeding means, if these things arise means, inbreeding will be more in the population, selection become highly efficient in the fixation and elimination of alleles. If inbreeding is more because, we know due to inbreeding our homozygosity is increased. So, within a couple of generation of inbreeding our frequency of small a small a allele will be very less. Ok! So, while the population of capital A capital A will be extremely high. So, our selection may be drifted in a particular direction.

Now inbreeding intensifies the effect of selection, by increasing the likelihood that offspring inherit identical alleles from both parents. So, inbreeding intensifies the effects of selection, by increasing the likelihood that offspring inherit identical alleles from both the parents. Ok! What I was talking earlier means, if inbreeding is done again and again the frequency of capital A capital A will be more. So, in its progeny in the next generation the frequency of capital A allele will be more, if frequency of capital A allele will be more, then definitely capital A capital A combination will be more. Ok! That the increasing the likelihood that offspring inherit identical alleles from both the parents, from both the parents it may get capital A allele identical alleles could be observed.

So, increasing the impact of selection more pronounced in shaping the genetic composition of the population. So, in this way the population may be shifted towards capital A capital A only, in spite of getting earlier the composition was this. Now, if selection is done if capital A is favorable, ok, then in this way finally, the population could be moved over here only capital A capital A will be left in the scenario in the population. So, now we will be discussing about some mathematical problems on Hardy-Weinberg equilibrium ok. So, what we know from the Hardy-Weinberg equilibrium just for recapitulation, you can rethink that we found that $p + q = 1$ in the population where, small p was the frequency of a particular allele the frequency of dominant allele while small q was the frequency of recessive allele ok that thing is already known to us.

Now let us start with some numerical. So, over here a question is given suppose, allele capital A determines the blue color in flower, and allele small a determines the white color of flower. If 64 white flower plants are available in a garden of 400 plants calculate the percentage of homozygous, capital A capital A plants and heterozygous plants in the population assume the population is in Hardy-Weinberg equilibrium. So, what we got from here, here from we are getting that capital A 2 alleles are there, for this gene capital A and small a while, capital A is responsible for blue color flower, blue color flower. It means, capital A capital A, as well as capital A small a, both will show blue color right, while, small a allele is responsible for white color.

So, we are assuming that small a small a is giving the white color. Now in the field how many plants were there, in the garden 400 plants were there. So, out of those 400 plants what we found 64 white plants are available means, 64 plant are there which are producing white flower, and rest of the plants means, these plants, these plants are making blue flower. Ok! So, this is already we have. Now what we need to know, we need to calculate the percentage of homozygous capital A capital A plant and heterozygous plants in the population.

So, before calculating the homozygous capital A capital A plants or the heterozygous plants, first we need to think about the Hardy-Weinberg basis. Ok! So, we have to assume, we know that capital A is the dominant allele over here. Ok! Suppose, the frequency of capital A allele is small p, we have to suppose it and the frequency of small a allele is small q, this is our assumption and if this is true, then the frequency of capital A capital A, what will be it, will be small p^2, the frequency of capital A small a means heterozygote individuals, it will be 2pq and frequency of small a small a, i.e. homozygous recessive individuals will be q^2, right? Now these two types, capital A capital A as well as capital A small a they will produce blue color. If we start calculating from there, it might be difficult and this one is given the small a small a individuals which is basically, producing the white flower its frequency is q^2 i.e. given over here.

So, we should start from here. So, we have q^2 is 64 individuals out of 400 plants, ok means, it is a frequency, right? So, we have to calculate in that way. Ok! So, in this way we can get the frequency of q^2. Now if we get it, we can calculate q it will be 0.4.
Now once we will know q, the frequency of a particular allele then we can calculate the frequency of another one, we know that $p + q = 1$; $p = 1 – q$; i.e. $1 -0.4 = 0.6$. So, now we got the frequency of capital A allele, earlier we got the this is the frequency of small a allele. Now we got the frequency of capital A allele.

Now what we have to calculate we have to calculate the frequency of capital A homozygous dominant plants right, the percentage, we have to calculate the percentage. Now the capital A plants it will be p^2, p^2 means $(0.6)^2$ =0.36 =36%, is not it the 36% plant will be capital A capital A or homozygous dominant plants. Ok! What will be the percentage of the heterozygous individuals? The percentage of heterozygous individuals will be 2pq right means, $2x0.4x0.6 = 0.48$ i.e. 48%. Ok! The frequency of heterozygote was 48% ok, these two has been asked over here. Now let us see, means, let us try to think whether we are going in right direction or not. So, what will be the frequency of small a small a? It will be q^2 right, q^2 means $(0.4)^2$, i.e. 0.16 = 16%. So, what will be the total percentage in the population? What we got? We got 36 of capital A capital A, capital A small a it was 48, and small a small a was 16, let us see and we are getting 100%. So, we have verified also it has not been asked. So, in this way we have to solve the mathematical problems associated with the Hardy-Weinberg equilibrium. Ok! So, here in the question, it was asked calculate the percentage of homozygous individuals they, have not asked about the number of individuals. If they ask about the number then we have to multiply this with the 400 plants, because total number of plants were there 400. Ok!

We have to multiply the frequency with these 400 plants in this way we could calculate the total number of individuals. Now coming to next question, that is related to Hardy-Weinberg equilibrium this one also. So, over here it is given in a certain population 8 people among 200 persons born with sickle cell anemia, 8 people among 200 persons born with sickle cell anemia. Calculate the number of individuals who enjoy the selective advantage of sickle cell anemia, as well as increase resistance to malaria. Assume the population is in Hardy-Weinberg equilibrium and homozygous dominant individuals are prone to malaria. Ok!

So, before discussing this particular question, we need to little bit understand how the sickle cell anemia or malaria, this thing works basically. So, it has been found that generally this small s small s means, we can assume that the smallest individuals, individual having homozygous recessive gene, they show the sickle cell anemia. While, for S gene 2 alleles are there, capital S and small s. Ok! It has been found that in certain population, among certain population this sickle cell anemia the individuals, having this sickle cell anemia they will face a lot of problem means, they cannot sustain for longer period of time. So, capital S capital S as well as capital S small s should be better because the detrimental allele small s .. it is avoided.

So, both things should sustain properly in the population, but normally it is found that in certain populations, the individuals having capital S capital S alleles means homozygous dominant, they are found to be susceptible to malaria. The homozygous dominant of this particular allele, of this particular gene was found to be susceptible to malaria. While, the homozygous recessive is definitely susceptible to sickle cell anemia they are also prone to danger. So, only this one will be beneficial in the population capital S small s. So, it is an classical example of over-dominance hypothesis.

In our last class, we have discussed about dominance hypothesis and over-dominance hypothesis, according to dominance hypothesis of heterosis and inbreeding depression, according to, dominance hypothesis capital A is equivalent to capital A small a, capital A capital A is equivalent to capital A small a, right? The deleterious gene, its effect is masked by the dominant counterpart, i.e. the dominance hypothesis. According to, over-dominance hypothesis, what we found capital A is always better than capital A capital A or small a small a according to over dominance hypothesis, and this is the sickle cell anemia and malaria, this interplay is the classic example of over-dominance hypothesis here. This people the genotype having capital S small s will be favored in the population. So, anyway so let us assume, the population is in Hardy-Weinberg equilibrium and we need to calculate the who enjoy the selective, we need to identify the number of individuals who enjoy selective advantage of sickle cell anemia, as well as increase resistance to malaria means, they will be prone to sickle cell anemia they will not show disease, and they will not show malaria also means, our target is to getting the capital S and small s individuals.

So, what we got over here 8 people are showing sickle cell anemia (ss) out of 200 person, right? It means we can calculate q^2, let us assume, the capital S capital S is frequency is p^2, the capital S small s its frequency is 2pq and small s small s its frequency is q^2, small s small s is showing the sickle cell anemia. So, its frequency is q^2 we can calculate it 8 people out of 200 persons, right, means, it will be 4/100 = 0.04

If q^2 is that, then q will be 0.2, once we get the q, once we get the value of q we can calculate the value of p, because p + q = 1; p = 1- q; i.e. 1 - 0.2 = 0.8; we got the frequency of capital S allele now. Now what is our target? Our target is calculating the number of individuals who enjoy the selective advantage. So, first let us calculate the frequency of heterozygous individuals.

Let us calculate the frequency of heterozygous individuals it will be 2pq right, means, 2x0.8x0.2 = 0.32, right? Now we have to calculate the number not the frequency, we have to calculate the number of individuals. Ok!

So, it is simple the number of individuals which will show the selective advantage to sickle cell anemia and the malaria, which are showing select, number of individuals which will show selective advantage to sickle cell anemia, as well as malaria it will be total person was 200x0.32. Ok! We have to calculate in this way means, 64 will be the number of individuals, which will be like this. Now can calculate the number of individuals which were means, which might be showing sickle cell anemia just to confirm whether we are going in the right direction or not. What will be the number of individuals which will show the sickle cell anemia? It will be our, q^2 what is the value of q? Value of q we got 0.2 means, $q^2=0.04$ right, means, the number of persons having sickle cell anemia it will be 200x0.04 = 8 means, we had it already. So, we are going in the right direction. So, in this way first we need to identify the homozygous recessive individuals. Ok!

Then our analysis will be easy. If we cannot identify it, then we need to calculate the frequency of different alleles. Earlier, we have shown how the frequencies are calculated. Ok! In this way we can calculate the frequency of different alleles. So, that is all regarding our class on this particular Hardy-Weinberg equilibrium or population genetics. So, this is the reference you guys can go through it and try to understand the topic properly through this particular lecture. Thank you.