Course Name: Basics of Crop Breeding and Plant Biotechnology

Professor Name: Dr. Joydeep Banerjee

Department Name: Agricultural and Food Engineering

Institute Name: Indian Institute of Technology Kharagpur

Week: 04

Lecture -16: Degree of Inbreeding and Genetic Basis of Heterosis and Inbreeding Depression

Welcome back. So, we will continue again. So, now we will be discussing various effects of inbreeding. First of all, appearance of lethal, sub-lethal alleles in the population. Suppose, we had a population of capital A small a and capital B small b, here the small a allele is lethal for the plant. I am telling it once again, suppose the small a allele is lethal for the plant.

Let us assume, if small a allele is there, the chlorophyll is not produced not at all means, the chlorophyll production is completely hampered. So, in these parents, the parents having plant having small a small a genotype cannot sustain, because without chlorophyll formation it cannot sustain. While let us assume, the small b genotype, the small b allele is responsible for some factors that is involved in photosynthesis. It is responsible for formation of certain factors in photosynthesis.

So, if small b small b genotype is available, then the photosynthesis will be reduced. We can see reduced photosynthesis, just assume. So, we had this plant and suppose we are selfing these plants. Selfing is the highest level of inbreeding. Suppose we are attempting selfing over here.

So what we will get, once we self this particular plant, in next generation we will get different genetic combinations, something will be having capital A, something capital B something. Over here capital A or capital small a allele could be available over here. While, over here also capital B or small b allele could be there means, the genotype may be capital A capital A capital B capital B, it may be capital A small a capital B capital B, or capital A small a capital B small b, these different combinations could be there, at least one dominant allele is available for both the genes. Such type of combinations could be available while, we will be having some genotypes, where, capital A will be available, but for B will be getting small b small b individuals. Some plants will be small a small a, but capital B and some other alleles of B will be available over there, and fourth type will be getting small a small a small b small b.

So these four things will be available in 9: 3: 3: 1 ratio. If you recall the dihybrid cross of Mendel, if you do the dihybrid cross of these genotypes, will get this type of combinations in 9: 3: 3: 1 ratio. So, what we told earlier, we are telling that small a allele is lethal. So, if lethal alleles are available in homozygous conditions so this plant will be killed. So, if we do inbreeding the appearance of lethal and sub-lethal allele will be more.

Over here our sub-lethal allele will be more, it will be in homozygous condition, and we can see the stunted growth the lack of photosynthesis will be done, in those plants. These plants will also be killed due to availability of small a small a, as well as the small b small b is there, the sub-lethal alleles are there. In this way if we do inbreeding, the appearance of lethal and sub-lethal alleles will be more. Next one reduction in vigor, that is also observed because as the lethal and sub-lethal alleles are available, due to formation of sub-lethal alleles that can show the chlorina/albina types of phenotypes, that can show stunted growths. So ultimately, we can see the reduced vigor in the plants their initial growth become very slow.

Next one is reduction in reproductive ability, from our earlier discussion also you can tell if the genotype becomes small a small a capital B capital B, then it cannot sustain at all if we get the genotype of small a small a small b small b due to inbreeding, it will not sustain if small a allele is lethal in nature. While in this case suppose we are getting capital S capital S small b small b, here the photosynthetic ability will be less. So, its production will be also less, maybe this gene might be responsible for something associated with the pollen formation. So, if the pollen grains are not formed properly ultimately, the reproductive ability will be hampered, and we can get lesser yield from the plant. So in this way the reduction in reproductive ability is also observed due to inbreeding.

So all things are associated with the involvement of various deleterious genes or the genetic load of the crop. If in a crop, if in a cross-pollinated crop, the genetic load is more means, number of deleterious genes are more, then we can see these things in more pronounced way means, in a huge way. Next one, is increase in homozygosity, i.e. also true. So, it is stating that if we do continuous inbreeding, if we do inbreeding the homozygosity is increased. Suppose just we are taking this, as our F_1 and we are doing selfing if, we do selfing, selfing is the highest level of inbreeding, through selfing what we can get capital A capital A, capital A small a and small a small a means, this will be 25%, this will be 50%, and this will be 25% means, in one generation of selfing or for one generation of inbreeding our heterozygosity percentage which one was 100% over here, it has been 50% means, our heterozygosity percentage is reducing and the homozygosity percentage will be increased.

If we do selfing again our homozygosity will be close to 75%, in this way through inbreeding the homozygosity is increased. Next one, the segregation of population in distinct line that is very important, the segregation of the population in distinct lines. Suppose, we have attempted a cross in these plants, we have attempted selfing in these plants, ok, after a couple of generation of selfing we will be having some plants having this genotype, some plants will be having this genotype, some plants will be having these genotypes, some plants will be having these genotypes, in this way different homozygous lines could be generated if we do inbreeding again and again. Along with that some heterozygous combinations will be also there, ok, because in cross-pollinated species in most of the cases full selfing is not done, why it is not done later on we will discuss. Ok! But if inbreeding is done in this way, the homozygosity could be arise for different genes right.

Just assume, in maize the small b allele is responsible for cob length, ok, let us assume, this is responsible for cob length while, the small c allele is it is responsible for number of seeds, number of seeds per cob, ok, just assume. So, if small b small b is available, the cob length will be shorter while, if capital B capital B is available then the cob length will be larger, just assume. Ok! So over here our cob length will be less, and we will see less seeds also right, while, in these plants our cob length will be fine, our cob length will be more, but will be having less seeds. Ok! In this way the population will be segregated into distinct lines, the different lines could be generated, ok, because over here small c small c genotype is there, so we can see less seed formation. Here small b small b is there as well as small c small c is there.

So here less, lesser cob size as well as less seeds will be available. Ok! So, in this way the population will be segregated into distinct lines. Now another one, is reduction in yield that is also observed, in case of inbreeding, if we do inbreeding in case of cross-pollinated crops, mostly due to presence of different lethal, sub-lethal alleles after a couple of generation of inbreeding, we get very few lines are surviving. So ultimately, our yields will be hampered also, ultimate yield will be hampered. So now we will be discuss about, we will be discussing about the different degrees of inbreeding depression.

So in case of certain crops like lucerne, carrot their high inbreeding depression is observed, high level of inbreeding depression is observed. If inbreeding is done then within a couple of generation, we may see only 25% production compared to the open pollinated variety, means 75% yield loss could be observed over there, in these crops compared to open pollinated variety after a couple of generation. So those crops show high inbreeding depression. Next one, we have some other crops that show moderate level of inbreeding depression like maize, jowar, bajra those crops so moderate level of inbreeding depression. In these crops after a couple of generation of inbreeding, we can see approximately 50%, yield reduction or 50% reduction in seed producing ability compared to the open pollinated conditions.

Then some crops they show low inbreeding depressions, those are also cross-pollinated crops, like cucurbits maybe some of you can grow bitter-gourd in your kitchen garden, and if you procure hybrid seeds from the market, and if it fruits, what you will be getting in first generation, if you keep those seeds, if you grow it for a couple of generation then you can see the fruit size will be reduced. The fruit size of the bitter-gourd will be reduced in next generation. In this way you can see also low inbreeding depression in case of cucurbits. Their fruits will be produced but its size will be lesser. While, some crops are there they do not show any inbreeding depression, those are self-pollinated crops, because in self-pollinated crop due to homozygous balance they try to maintain the homozygosity.

Now if any deleterious allele available over there, what could be the scenario? Let us see, suppose, in a self-pollinated plant its genotype was capital A capital A capital B capital B it is a self-pollinated crop. Somehow a mutation has occurred over here, and we got a genotype capital A capital A and capital B small b. Due to mutation this genotype has been formed. In case of self-pollinated crops, they usually do selfing generation after generation and through selfing it will produce seeds. So, in its next generation if selfing is done will be having capital A capital A capital B small b, will be having capital A capital A capital B capital B, will be having capital A capital A small b small b, because for this gene only different recombinants will be produced.

So, if you think about the homozygous balance, they will try to maintain the homozygous balance in the population. Again, let us think that, the selfing is being done for another few generations and if the small b allele is deleterious for the crop, if small b allele is deleterious for the crop… So, this plant will be killed in the field suppose, it cannot produce any, it cannot produce any chlorophyll. So, the plant cannot sustain if it is deleterious naturally it will be eliminated from the population. So, if we go to next generation of selfing, next generation of selfing again the capital A capital A capital B capital B its homozygosity will be increased, right, while, the heterozygosity will be reduced, heterozygosity will be reduced due to selfing again and again.

And due to this selfing, if this type of line arise it will be killed eventually, as it is a self-pollinated crop they will try to maintain the homozygous balance, homozygosity is their basic things. Ok! So, if any deleterious alleles come in self-pollinated crop, due to natural selection during the course of selfing again and again in different generation finally, those deleterious alleles could be removed from the population mostly it could be removed. Ok! So, in this way the no inbreeding depression is observed in self-pollinated crops. So, whatever the genotype will be having, they will be having those genes that are not too much deleterious for the plant. ok! So, those are not detrimental in homozygous condition, homozygous dominant or homozygous recessive conditions.

Anyway now gradually, we will discuss the genetic basis of heterosis and inbreeding depression. So, we will be discussing about 3 different hypotheses over here, first one is dominance hypothesis, next one is over dominance hypothesis, and third one is epistatic hypothesis. So, according to dominance hypothesis of heterosis, heterosis is not due to heterozygosity, but heterosis is due to the dominance nature of a particular gene, of a particular allele of the dominant allele. Ok! Later on, I will tell it was proposed by Davenport and later on it was explained by Bruce, Keeble and Pellow. So, according to this hypothesis suppose, 2 alleles are there capital A and small a, for a particular gene one parent was having capital A capital A genotype, another one is having small a small a genotype.

While, this parent was having small b small b genotype, and this parent was having capital B capital B genotype, ok, this was 2 parents. So, according to dominance hypothesis the heterosis is due to masking of deleterious recessive allele by the dominant allele. So, here the recessive alleles are deleterious, it is assumed that the recessive alleles are deleterious. So, as in this plant this recessive allele is available. So, some deleterious effects might be there while, in this plant for aging the recessive allele is available in homozygous condition.

So, it could be deleterious also, and if we cross between them, we will get capital A small a and capital B small b, if cross is made between them in F_1 will be getting this.

So, here for each of the deleterious allele the capital A small a, as well as small b allele the dominant counterpart is there. Ok! So, it will mask the effect of the deleterious allele. Now it is directly proportional to the number of dominant gene contributed by each parent. So, if number of dominant gene is more and means, basically, the cumulative effect of the dominant genes coming from both the parents will show the heterosis according to this hypothesis.

So, I am telling it once again, the cumulative effect of dominant alleles coming from 2 different parents in F_1, will show the heterosis according to this hypothesis. So, let us take an example of 2 different parents capital A capital A small b small b capital C capital C small d small d, this is one parent and another parent is having small a small a capital B capital B small c small c capital D capital D. So, I have just underlined the deleterious genes. Ok! I have just underlined the deleterious genes. Suppose the A gene, ok, suppose the A gene is responsible for or number of cobs in maize, ok, suppose, the B gene is responsible for resistant or susceptibility to some disease, disease resistance. Ok!

Suppose, C gene capital C or small c that is responsible for number of seeds per cob, and suppose capital D or small d is responsible for the cob length. So, in all these cases if recessive allele is there, then it is, we can see the negative impact. Ok! Suppose if small a small a will be the genotype, the number of cobs will be less in the plant. If capital A is there then the cob number will be more, the production will be more. If small b small b allele is there, we can see disease susceptibility.

If capital B is there, maybe we can see disease resistance. If capital C will be there then number of seeds per cob will be more, but if small c small c will be there then the number of seeds per cob will be less and over here suppose, for D gene also it is determining cob length. If small d small d is there the cob length will be smaller. Ok! So, by considering these things maybe we have considered two different plants, ok and for each of these things we have provided some values. At least one dominant allele is there, then we are giving the value 2 while, if the homozygous recessive alleles are there, we are giving the value 1.

So, here small b small b was there, for that let us assume, we are giving some phenotypic value 1. The small d small d is there, for that we are giving a phenotypic value 1. So, in this parent the phenotypic value was 2, 1, 2 and 1 = 6 was the phenotypic value. Ok! For 2 genes homozygous recessive condition was available. If you consider out another parent, the second parent over here for A and C gene the homozygous recessive condition is there.

So, let us assume, the phenotypic value of 1 and 1 while, for the B and D genes we are getting value 2 because, at least one dominant allele is available. So, now what will be our F_1? Our F_1 will be having capital A small a capital B small b capital C small c and capital D small d, because here from only one type of gamete will be produced, capital A small b capital C small d, this gamete will be produced, and here from small a capital B small c capital D this gamete will be produced, due to fusion of these two gametes ultimately, we can get this genotype right. So, if you see here none of the genes, none of the alleles are available in homozygous recessive conditions. So, here we may consider the phenotypic value as 2 + 2 + 2 + 2 = 8. So, you can see this is heterotic compared to both the parents because here the phenotypic value was 6, here the phenotypic value was 6 and here we are getting phenotypic value 8.

So, in this way according to dominance hypothesis the heterosis is observed in F_1 due to masking the effect of the deleterious genes or deleterious alleles by its dominant counterparts. So, according to this hypothesis, some objections are there, what is first objection? So, if you carefully think about the dominance hypothesis, over there the capital A capital A its phenotypic value, was given to the small a small a its phenotypic value was given 1 while, in capital A small a here the deleterious effect of small a was masked by the capital A, it was also given phenotypic value 2. It means the capital A capital A is equivalent to capital A small a, is not it the capital A capital A is equivalent to capital A small a. So, if this is true, if the dominance hypothesis is true, we may get some of the inbreds which will be as vigorous as hybrids. If we do selfing in maize or different cross-pollinated crops we can develop inbreds.

How inbreds are developed? Inbreds are developed by mating between individuals which are close to their descent or ancestry, and after of couple of generation of inbreeding we can develop inbreds, and those are strictly maintained by selfing or other different inbreeding methods. So, through this approach, through this hypothesis we might get some of the inbred lines, whose genotype will be capital A capital A capital B capital B capital C capital C capital D capital D and it should be equivalent to capital A small a capital B small b capital C small c and capital D small d it should be equivalent, but naturally we do not see this. So, this is one objection raised against the dominant hypothesis. Next one, is symmetrical distribution in F_2. If you think about the F_2 distribution suppose, this one was the F_1, what could be our F_2? in F_2 we will see capital A capital A, capital A small a and small a small a, right?

So, if dominance hypothesis is true, out of these individuals 75% will be this, and 25% will be this means, 3: 1 segregation is expected in F_2, because according to dominance hypothesis capital A capital A is equivalent to capital A small a. So, in F_2 3: 1, 3 will be our superiority three-fourth, and one-fourth will be inferior, this type of segregation could be observed, but generally in F_2, we can see the symmetrical distribution. Ok! In different plants, if we consider yield, or other different traits, if we consider then, we can see symmetrical distribution. Ok! So, how can we explain these objections? First explanations, basically, for the first things let me explain it. So, Jones suggested that the quantitative characters in the cross-pollinated species, most of the characters a lot of quantitative characters are available.

What is quantitative characters? The characters which are controlled by many genes. Ok! So, over there we may see some kind of linkage, we may see some kind of linkage over there. Suppose we had two plants one is P_1 one is P_2, in P_1 our genotype was capital A capital A small b small b, in P_2 our genotype was small a small a capital B capital B. ok! And let us assume, that these two genes are tightly linked. So, in P_1 let us assume in a particular homologous chromosome, we had these two genes, here capital A and small b over here, capital A small b was available.

In P_2 here, our genetic constitution is small a small b capital B capital B two genes are available in this condition, small a capital B and small a capital B in another homologous chromosome. If cross is made in F_1 what we will get, in F_1 one chromosome will come from here, one chromosome will come from here. So, we will be getting this combination, capital A small a capital B small b this combination will be observed in F_1, but if we go to F_2 or subsequent generation as these two genes are tightly linked, if linkage is available then the combination will not be possible between them. So, whatever we will be getting in next generation, capital A always will be staying with small b or small a will always be staying with capital B. So, in this way capital A and capital B could not be observed could not be obtained.

So, such type of inbreds will not be possible to get ok, but in F_1 we can see the heterozygosity, in the figure because the dominant and recessive values for both the genes could be available. Another one regarding the symmetrical distribution, regarding the symmetrical distribution, if large number of genes are there. Suppose, if we are considering one gene, then we can see 3: 1 ratio, right? If we consider two genes governing a particular trait then we can see 9: 3: 3: 1 ratio. In this way if we consider 3 genes, 4 genes more number of genes are involved, if for governing a particular trait then this ratio will be more.

So, ultimately in spite of getting skewed distribution 3: 1 kind of distribution will be getting a symmetrical distribution. There are some plants will be inferior, some plants will be intermediate, and some plants will be superior. These types of things will be available if that traits are controlled by large number of genes. Ok! Thank you.