Course Name: Basics of Crop Breeding and Plant Biotechnology

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Lecture-01: Mendelian Genetics

Hello everybody, this is Dr. Joydeep Banerjee from Agricultural and Food Engineering Department of IIT Kharagpur. So, welcome to the SWAYAM NPTEL course on Basics of Crop Breeding and Plant Biotechnology. So, today we will discuss the first module of this particular course i.e., on Concept of Gene and Mendelian Genetics. So, the first lecture will be on Mendelian genetics and thereafter, gradually we will move into the concept of gene part. So, in this particular course we will be covering, what is genetics? What is heredity? What is variation? How different variations are generated within different crop species? Then, how alleles are developed? Then, we will discuss about the important Law of Mendel i.e., Law of Segregation, then, we will discuss monohybrid cross.

We will also discuss the second Law of Mendel, i.e., Law of Independent Assortment, then, we will discuss the dihybrid cross and finally, we will discuss about the linkage and incomplete dominance where, the Mendel's principle could not follow these particular things. So, first of all, what is genetics? So, genetics is the branch of science which deals with the study of heredity and variation. So, two different terms are there, one is heredity and another one is variation. What is heredity and how variations are raised, gradually we will discuss.

Then, genetics also study several genes and their inheritance, means different genes are available in each and every individual like in rice, almost 30,000 genes or more than that number of genes are available. Then genetic study also investigates the different types of genetic variations available in an individual and what are the different mutations? How can we use those particular mutations available on the germplasm? And this study is very

crucial for understanding heredity, genetic disorders and biotechnological applications. So, here you guys can see two different examples, like here, variety A and variety B of two different rice varieties are shown here. Ok! So, if you see from the husk color, one is straw colored in nature and another one is relatively blackish in nature.

So, based on that, morphologically we can distinguish these two varieties. Definitely some genes are there those are responsible for this husk color. So, this is the study of genetics through which we can trace out that particular gene or we can apply that gene in plant breeding. Here, we can see two different lentil genotypes, genotype A and genotype B. Ok! If you see the genotype A of lentil, those are larger in size, the seed size is larger i.e., the macrosperma kind of lentil genotypes, while, the genotype B is microsperma kind of lentil genotypes those are smaller in seed size.

So, definitely some genes are there which can cause such type of difference and eventually we can trace these genes and we can play with those genes for the advancement of plant breeding, gradually we will discuss about those things. Now, coming to the part what is heredity? So, heredity is transmittance of traits and associated genetic information from parents to their progeny. We know that, among the human beings some of the individuals possess curly hair, some have straight hair. So, if we try to find out that where from these genes are coming? If we study their parentage maybe we can get the answer because from each and every parent some traits are transferred to its progeny. Ok! So, from parent to progeny some traits are transferred.

Basically, the eye color in human beings, the skin color, those also comes under this type of analysis through heredity we can study these things. So, the heredity is also known as inheritance, transmission of traits from one generation to next generation and trace traits, each and every trait can pass on to the offspring means next generation, either through sexual reproduction or through asexual mode of reproduction. Now, what is sexual mode of reproduction? In sexual mode of reproduction male and female gamete has to fuse. It is true for most of the animals as well as in most of the plants. Ok! Because, the pollen grains produced from a particular plant can fertilize the egg cells produced in the same plant or in different plant. Thereafter, fusion of male and female gametes is taken place and finally, zygote formation and seed formations are taken place through sexual reproduction.

In human beings also sperm cells are produced by male gamete, male parent and egg cells are produced from the female parent and finally, through successful fertilization we can get the zygote formation and finally, we can see the offspring, i.e., the sexual mode of reproduction. So, through sexual mode of reproduction the heredity could be transmitted. We will discuss about these things later on also. Through asexual mode of reproduction also a character could be transmitted. Suppose in some crops, in sugarcane we know that if the stem cuttings are used therefrom, we can get a full-grown plant.

In some sugarcane you can see the stem diameter is lesser or narrower. Ok! So, in next generation also we will get almost similar kind of progeny. So, i.e., the transmission of heredity through asexual mode. You have seen a lot of bougainvillea plants in different parts. Ok! So, bougainvillea plants are very common.

So, how this plants are reproduced? If we cut a particular bougainvillea plant cutting, means if you collect the cutting of that particular stem and we sow it in the soil, in a few months we can see root formation and after few months we can see it will start blooming. And almost similar type of flower we can see, similar colored flower we can see in the new progeny of the bougainvillea. So, this is asexual mode of reproduction. Here also, the traits are transferred from one generation to next generation. So now, how the transmission of DNA is taken place in human? We know that we human beings has 46 number of chromosomes. Ok!

So, we have to rephrase it basically 23 pairs of chromosomes are there in human beings. Out of these 23 pairs means, each pair is the similar kind of chromosome like chromosome number 1 is present in 2 copies, chromosome number 2 is present in 2 copies in this way, 23 pairs of chromosomes are there. And out of this total 46 chromosomes, 44 autosomes are there and 2 sex chromosomes are there in human beings. In case of male, we will be having sex chromosomes X and Y, while in case of female we get, means, we found that XX sex chromosomes are available. So, let’s see how the DNA is transmitted from human in one generation to next generation.

So, it is a male parent, male parent is having 2n=46, 2n=46 while, the female parent will be also having 2n=46 means, 23 pairs of chromosomes are available in male parent and

female parent. So, during sexual reproduction, the male produce sperm cells and sperm cells will be having 23 number of chromosomes means, from each pair one set of chromosomes will be coming in the sperm cell, while from the female parent also one particular chromosome from each set will be coming i.e., total 23 chromosomes will be coming in the egg cell. Thereafter, fusion is taken place between sperm cell and egg cell and finally, we can see the offspring by the fusion of 23 chromosomes from male parent and 23 chromosomes from female parent. So, finally, in the offspring also we are getting 2n=46 means, 46 number of chromosomes will be there. In this 46, 23 is coming from male and 23 is coming from the female.

So, now gradually we will move into the Mendelian genetics. Ok! So, who was Mendel? His full name was Gregor Johann Mendel. He was born in Austria, now it is Czechoslovakia in 1822 and he was a priest in the church and he developed keen interest to study the genetics of pea. Pea plant is known to us as sweet pea, i.e., *Pisum sativum*, its having 2n = 14 means 7 pairs of chromosomes are there in pea plant. So, basically Mendel started his experiment in at around 1857 and before starting his experiment he collected seeds from all across the Europe, different parts of the Europe, therefrom he collected the pea seeds and he started his experiment and at last he postulated 2 laws namely Law of Segregation and Law of Independent Assortment.

So, these 2 are very important laws of Mendel and that basically started the construction of genetics. Hence, Mendel is known as the Father of Genetics. So, after 7 long years of experiments, he published his findings in a paper titled ‘Experiments in Plant Hybridization’. So, why did he choose pea plant? Some basis was there, first of all the pea varieties were easily available on commercial basis in different parts of the Europe. It was a famous crop over there and at that time also, a lot of people used to cultivate pea and so the commercial seeds were available in different parts and he collected those seeds from different regions.

Then, the most important thing is that, the presence of 2 contrasting forms of many characters were available over there. Means for different traits like plant height, some plant was tall, some plant was dwarf. So, it’s a contrasting trait. So, this type of different

contrasting traits was available in different pea plants in different pea genotypes. Next one, pea is self-pollinated in nature.

So, what is self-pollinated? What is self-pollination? Self-pollination is the fact that if the male gametes produced by a particular flower can fertilize the female gamete produced by the same flower, then it is known as self-pollination. Male gametes are produced by anther, in anther the pollen grains are produced, pollen grains are male gametes. So, those pollen grains can fertilize the stigma of the same flower in self-pollinated plants. Ok! As it is self-pollinated in nature, he could easily control the crossing and subsequent generation because, no factors could be coming from any other plants. Ok!

So, he chose pea plant. Now it is an annual plant, basically in a few months, its life cycle is completed. Suppose, if he could choose a tree plant maybe after 5 to 7 years it's flowering will come, then seed formation will take several months. So, his experiment could be delayed. So, he had chosen an annual plant. So, that within a few months whatever the crossing he will be, means he could made, he could get the result.

So, in this way, he planned the experiment. Then next and another important thing is that the flower size is large and the seed size is also bigger in pea. So, easily he could make some cross. So, basically how crossing is made gradually we will discuss in the next part of our course and next one is that, growing pea plants is relatively easier. It can grow in a pot; it can grow in the field easily and within a few months its life cycle is completed we have mentioned.

And next one, in pea plants pea flowers are complete flowers. Ok! So, these different parts are available over there. So, first of all in a complete flower will be having sepals, petals, androecium and gynoecium. So, in pea flower also we can see the sepals are there i.e., the base where the total flower will be staying on the plant. Then petals are there, the petals basically cover the reproductive parts of the flower in pea plant, in pea flower basically different petals are there, different sized petals are there, a standard is available there, two wings are available there and two keel petals are available there, those are boat shaped structure.

Now coming to the reproductive part of the pea plant. In the reproductive part, it has 10 stamens. Ok! And it is distributed in 9+1 orientation. You can see over here 9 stamens are staying together, while one stamen is staying aside. Ok! So, in these stamens, anthers are available and therefrom the pollen grains are produced, while this black colored one i.e., the female reproductive part. Ok! Here basically the stigma is available.

So, in self-pollinated plant, the pollen grains produced from this anther will sit on the stigma and thereafter, ultimately, the fertilization is taken place and finally, we can get the seed formation. So, as pea was a self-pollinated crop, it's a complete flower. So, his experimentation was pretty easy. So, now gradually we will discuss few things that will be coming again and again in our discussion. First of all, what is allele? Ok! Allele is the variant form of a gene i.e., located at the same genetic locus of the chromosome. Ok!

We human beings we have 23 pairs of chromosomes. So, what is chromosome? How the DNA is packed there? Later on, we will discuss, but chromosome we do have i.e., known to us. Ok! So, let's assume these are two homologous chromosomes. Ok! This one and this one, two homologous chromosomes mean, suppose it's chromosome number 1, 1 and 1′. So, in these two chromosomes at a particular position, may be in the short arm of the chromosome at a particular position in one homolog, P gene is there capital P gene is there, while in its homolog the small p gene is here. So, these are same genes, but alternate forms are there, alternate forms of a particular gene, those are allele.

How it is developed? Later on, we will discuss. Then, the position of a particular gene on the chromosome is called the locus. In this way, each and every gene has a particular locus, some genes are available close to the telomere region, some genes are available close in the long arm of the chromosome, some genes are available in the shorter arm of the chromosome, some genes are available in chromosome 5 only, some are available in chromosome 7 only. In this way each and every gene has a particular locus on the chromosome. Now coming to trait, what is trait? Trait is the physical or behavioral characteristics of an organism.

It may be associated with a particular feature or it may be associated with the overall plant, like a plant may be tall, a plant may be dwarf that's a trait means, we can see that's the

physical character. Ok! Now coming to the phenotype, phenotype is the set of observable physical traits means, we can observe it easily. Ok! Morphologically we can distinguish it. Ok! So, the morphological features of a particular individual in respect to a particular trait or overall is known as the phenotype of a particular individual. Like a plant may have black colored seed that's a phenotype, a plant may be tall means overall the plant is showing tall type i.e., also a phenotype, the black color may be due to a particular gene while the plant height may be controlled by a number of genes also, anyway. So, gradually during the course, means as the course will be progressed, this thing will be discussed again and again. Now what is genotype? Phenotype we have mentioned, i.e., the morphological features of an individual of an organism, but genotype is the genetic information or genetic basis of a particular morphology or a particular trait.

Suppose over here, you can see 3 flowers are shown. Ok! If you see the phenotype of first 2 flowers, they are purple in nature, while the third one is white in nature means white colored flower. Ok! So, phenotypically 1 and 2 are same and 3 is different, but if you try to think about the genotype then maybe in flower 1, its genotype is capital P capital P, means in these 2 loci of the homologous chromosome, in both the homologous chromosomes, capital P allele is available. So, this is known as the homozygous dominant. Capital P is dominant, why it is dominant later on I will tell. Then in this case in capital P small p, it is heterozygous in nature means, 2 different alleles are available in the homologous chromosome. While, if the 2 recessive alleles are available small p small p, then we can see the white colored feature, white colored phenotype. Ok!

So, 3 types of genotypes are mentioned here capital P capital P i.e., homozygous dominant, capital P small p i.e., heterozygous and small p small p i.e., homozygous recessive. Now, listen to it carefully, if you see about the homozygous dominant and heterozygous individual, here you can see only color of the flower is purple in both the cases. It means the capital P is the dominant allele. So, it is masking the effect of the small p allele. If the small p allele has any particular feature, its effect is masked by the capital P allele.

So, the capital P is dominant allele and the small p is recessive allele. Ok! So, this one is the homozygous dominant, capital P capital P and this one is the homozygous recessive, small p small p. Now, how different alleles are developed? Let's assume it's capital P allele

over here, this is the sequence of capital P and a plant is being grown in the field and due to some UV rays coming from the sunlight or due to some toxic chemical applications in the field finally, a mutation has been occurred. So, let's see, you can see the gene sequence here A T G C A G and T this sequence is there. So, if you know that from each and every gene which is the coding part first from the DNA region the mRNA is synthesized, if it is a coding DNA.

Then, from the mRNA finally the protein is formed. In protein basically 3 bases available on the DNA they will code for a particular amino acid. Ok! These 3 bases consecutive bases are known as codon. So, suppose in the capital P allele, 2 codons are there the first codon and second codon. So, the first codon codes for methionine and second codon codes for glutamine. So, in most of the cases, in most of the proteins the first starting codon is methionine. While, another plant which is growing in the field where the mutation has been taken place let's see how the mutation has occurred.

Suppose, initially the third base in codon 1 was G, then some mutation occurred over there and due to that mutation, it has been converted into C. So, if this sequence is converted into C, then definitely the codon will be also changing the triplet codon. So that, the subsequent amino acid will be changed in the protein also and now it has been isoleucine, while the codon 2 glutamine remain same. So, now just try to think in case of this particular allele, the full functional protein is being formed, while in this case, the protein may be not developed, the protein may not be developed properly because the first amino acid has been changed.

So, can you see any difference, we may see. So, in the first case where capital P allele was there, we are observing the purple color flower, while where the mutation has been taken place, their small p allele has been formed and we are observing white flower, white colored flower. So, in this way the alleles are developed due to mutation or due to application of different toxic chemicals, due to changes on the DNA, due to frame-shift mutation and different things, later on we will discuss those things. So, now coming to the 7 pairs of contrasting traits that are available in pea and Mendel used those traits in his experiment. First of all, for flower color he found 2 different colored flowers in pea, purple flower and white flower. The purple was dominant over the white one, for seed shape, he

found round seeded pea and wrinkled seeded pea, the round was dominant over the wrinkled one.

For seed color, he observed yellow colored seed and green colored seed, the yellow colored seed was dominant over the green colored one. For pod color, he observed green pod and yellow pod, the green pod was dominant over the yellow one. For pod shape, he found inflated pod and constricted pod, the inflated one was dominant over the recessive one. For plant height, he found tall plants and dwarf plant or short plants, the tall was dominant over the shorter one. And for the flower position, you can see, he found 2 different types also contrasting traits, i.e., axial, here flowers are produced in the axial part of the plant, while in another variant he found some plants are there, their flowers are produced at the terminal part.

So, these are the 7 contrasting traits taking considered these things, Mendel planned his experiment. So, now coming to Law of Segregation. So, according to Law of Segregation, the 2 alleles of a gene present in F_1 progeny do not affect each other. F_1, what is F_1 progeny? It is the first filial progeny, suppose two parents are crossed, then whatever the offspring will be made i.e., known as F_1, first filial generation. So, what this law is stating? The two alleles of a gene present in F_1 progeny do not affect each other they become separate and pass into different types of gametes in their actual form producing 2 separate types of gametes in equal proportion. Ok!

It means two alleles available in F_1 they stay together, but they don't mix during gamete formation for next generation, those two alleles are separated in its actual form in equal proportion. So, before understanding the Law of Segregation, we need to discuss little bit about cell division. So, two types of cell divisions are taken place in most of the eukaryotes, mitosis and meiosis. So, mitosis occurs in the body cells, i.e., known means i.e., responsible for normal growth and development. Ok! So, these are the 5 different phases which are occurred in mitosis, first one is interphase, then prophase, metaphase, anaphase and telophase.

So, during interphase, the DNA which is available inside of the chromosome those are present within the nucleus, those things are being discussed in mitosis and meiosis parts,

because genetics is mostly associated with genes, they are inheritance those things. So, we will cover these things mostly. So, in interphase you can see the DNA is available in coiled form, most of the chromosomes are available in coiled form over here. Then, gradually, the cell is going into the prophase, entering into the prophase then, the chromosomes are being condensed and we can see different chromosomes partially. So, here you can see two bigger chromosomes are there, two smaller chromosomes are there.

So, we can assume them that chromosome number 1 and 1′ and 2 and 2′. Ok! So, in prophase those chromosomes are mostly visible. So, coming to metaphase, in metaphase what happens? All the chromosomes, they lie on the metaphase plate of the cell, they lie on the metaphase plate of the cell. So, here also we can see 1, 1′, 2 and 2′, all chromosomes are lying here. Ok! So, thereafter once the cell division progress into anaphase, then each of these chromosomes are separated, means one chromatid from each chromosome is moving to a particular pole, while another chromatid of each chromosome is moving to another pole. Ok!

So, in this way, anaphase is taken place and thereafter, telophase is occurred there, the cell division is almost done and finally, those chromatids are eventually converted into chromosomes. So, what is the essence here? Initially the chromosome number was 4 and here two cells are being produced having 4 and 4 chromosomes means from one cell we are observing two cells and the chromosome number remains same. It is occurred during mitosis in most of our body cells, because just assume a baby is gradually increasing, his hand is increasing in size, his legs are increasing in size. So, the cells have to be multiplied from one cell, two cells are produced by mitosis in this way, because in each and every cell the chromosome number will remain same. Now during meiosis, meiosis is occurred in the reproductive tissue only.

In the reproductive tissue meiosis is occurred and at the end of meiosis, we can understand that the chromosome number is halved. The chromosome number becomes half of its original number. Ok! So that, different gametes which will be producing, they will be having one set of chromosomes. So, I am trying to explain the meiosis process, because later on we will discuss metaphase, anaphase again and again. So, during meiosis we have

not, means, we are not going to discussing the interphase part, we are starting from the prophase.

So, it has two sub division, two phases, the top one is the meiosis I, the bottom one is the meiosis II. In meiosis I, it is also divided into few parts, prophase I, metaphase I, anaphase I and telophase I. So, prophase I is the longest phase, here different things are occurred. First of all, in leptotene, you can see the chromosomes are gradually condensing, but still it is not properly visible.

Next coming to zygotene, their chromosomes are mostly available. So, we are assuming here just one chromosome is available. One chromosome and its homologous chromosomes is available, means one pair of chromosomes is here, 1 and 1′. So, in pachytene stage, pachytene stage what happens, there crossing over is taken place between the non-sister chromatids of homologous chromosomes. This is chromosome number 1 and this is 1′. So, those are homologous chromosomes and if you see about this blue color, this is one chromatid in chromosome number 1, while this yellow color is one chromatid in chromosome number 1′.

So, in between these two non-sister chromatids, the crossing over is taken place initiated in pachytene stage. In diplotene, basically we can see the chiasma formation there, some genetic exchange has been occurred between the non-sister chromatids of the homologous chromosomes. You can see some exchange of genetic elements have been occurred. In diakinesis, those things are gradually separated and then prophase I is over, then the cell enters into metaphase I. So, we have considered that only one pair of chromosome is available over here.

If you see in metaphase I, this pair will be lying in this way, in this orientation, the homologous chromosomes will stay in this orientation and thereafter it will move into anaphase I. In anaphase I each homolog will be separated and in telophase I finally, we will be having two cells, in one cell one homolog will be available, in another cell another homolog will be available. Means from two chromosomes over here, finally, we are getting one chromosome at the end of telophase I. Then gradually interphase will be occurring and

prophase II will be started. In prophase II, again, this chromosome will be partially decondensed in metaphase II, gradually condensation starts.

They come to the metaphase plate in each of the cell and in anaphase II, two chromatids are separated in each of the cell and in telophase II, finally, two cells are produced from here and two cells are produced from here. So, basically from two chromosomes, what was in the beginning of meiosis, finally, we are having four cells, each having one chromosome. Here, initially one cell was there and it had two chromosomes. Ok! So, the chromosome number is reduced, earlier we had two chromosomes, now we are having one chromosome, the chromosome number has been reduced and from one cell basically four cells are produced after meiosis.

So, meiosis is taken place during gamete formation. Suppose, in animals, the sperm cells are produced by meiosis, the egg cells are produced through meiosis. So, the chromosome number becomes half. In plants, the pollen grains are produced through meiosis, the egg cells are produced through meiosis. So, this is the basic, how the mitosis and meiosis is taken place. Thank you.