Soil Science and Technology
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Lecture – 19
Soil Temperature

Welcome friends to this new lecture of Soil Science and Technology.

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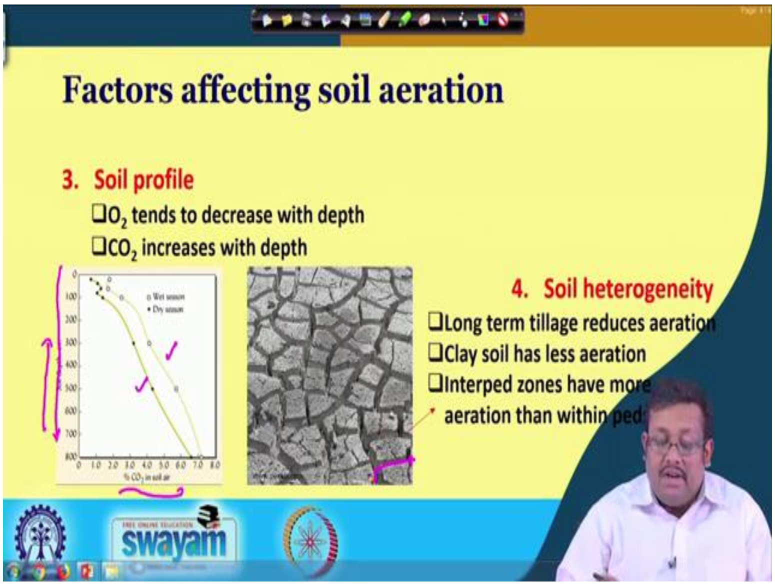

In the last lecture, we talked about soil aeration, and we discussed about different, you know, what is soil aeration and what are the different processes of soil aeration. We talked about diffusion, we talked about mass flow of gases. And then, we talked about different factors which affects soil aeration. And we started, you know, discussing about the factors which affects soil aeration, and I will start from those factors today and I will try to finish this by this lecture and then we will go ahead and start soil temperature which is another important soil physical parameter.

So, we were talking about factors affecting soil aeration. So, one of the major factor which affects the soil aeration is soil profile and you know that oxygen tends to decrease in the soil with depth and vice versa trend can be found in case of carbon dioxide because, carbon dioxide can be increased generally increased with the depth in the soil.

And also we have found that a soil heterogeneity is also, we know, in fact, you know, soil heterogeneity also influences soil aeration because, a long term tillage reduces the aeration and clay soil has less aeration, and interped zones have more aeration than within the peds. So, you can see that, we know, clearly in this graph that if you plot the percentage of carbon dioxide in x axis and in the y axis, if we put the soil depth in a meter you will see that the soil depth in centimeter, you will see that with the increase of a with the increase in depth from 0 to you know; the depth is increasing from this 0 to 800 centimeter and as a result of that increase in the soil depth, percentage of carbon dioxide in the soil air is increasing. And also, this increase in carbon dioxide in soil air is higher in case of wet season than that of dry season.

And also, you know, as we can see from this picture that these are clays, you know, these are soil which are showing the swelling and shrinkage properties as we have discussed in case of vertisol. And in this inter ped zones this shows more aeration than within the peds. So, this soil heterogeneity is also having an important function for controlling soil erosion soil aeration.

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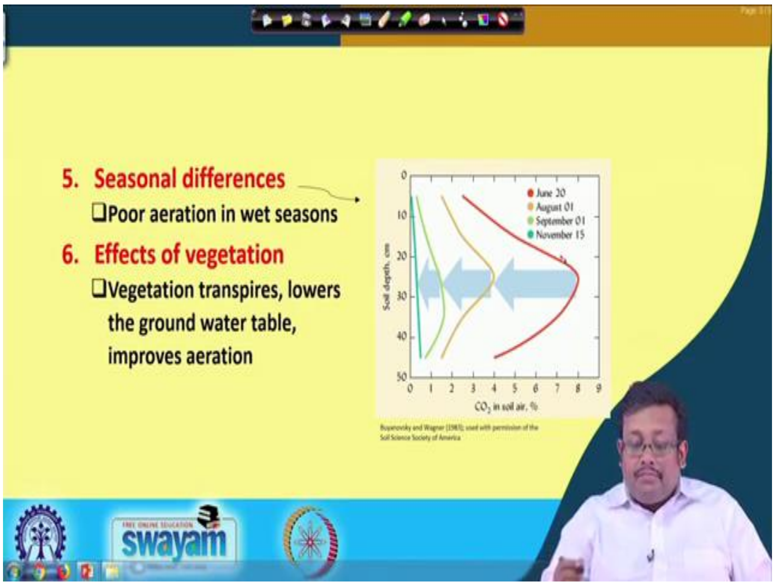

So, let us go to the next slide and see what are the other important aspects. While seasonal difference is one of the major factor for soil aeration. As we can see the that obviously we will get poor aeration in wet season in this graph we will see that as in case in case of monsoon season obviously which is denoted by this red solid line by June 20 and then August 01 September 01 and November 15 obviously the carbon dioxide increase in the soil profile increases in the wetted season than that of a dry season.

So, poor aeration will get in the wetted season, because of all the pore spaces are filled with water in the wet season. So, there, you know, ultimately creating very, we know, small chances of proper aeration. And effects of vegetation well, vegetation also transpires, lowers the groundwater table and as a result of that due to the lowering of the groundwater table, it improves the aeration status of the soil.

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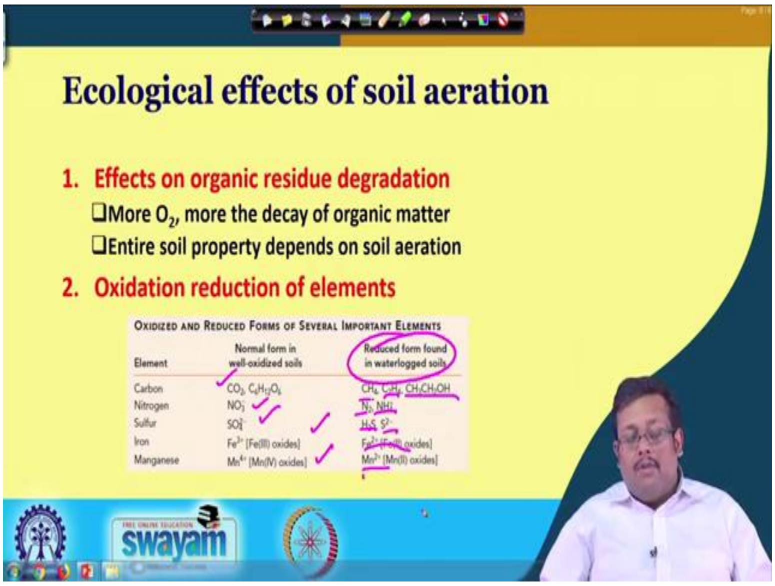

So, let us go to the next slide and see what are the other ecological effects of soil erosion? Well, effects on organic residue degradation is one of the major ecological effects on soil aeration. Because more oxygen, you know, helps in more decay of organic matter however entire soil property depends on soil aeration. Now oxidation reduction of elements is also important as you can see in this table these are different elements starting from carbon nitrogen sulphur and then iron and manganese and you can see a in the normal form in well oxidized soils and their reduced from found in waterlogged soils.

So obviously, in the normal forms of carbon in well oxidized soil is basically carbon dioxides, in case of nitrogen there is nitrate, in case of the sulphur there is sulphate, in iron it is Fe 3 plus or Ferric, in case of manganese it is Mn 4 plus or manganic. Whereas, in the reduced conditions these forms will be changed into reduced from like methane and ethylene in case of carbon. In case of nitrogen it will reduce to ammonium or elemental nitrogen, in case of sulphur it will reduce to either hydrogen sulphide or elemental sulphide, and then F e 3 plus will reduce to F e 2 plus or ferrous, and in case of Mn 4 plus it will reduce to Mn 2 plus, sometimes carbon will reduce to ethyl alcohol also.

So, you can see these are different forms which are present as a result of aeration status in the soil. Obviously, this oxidized form will be present when there will be more oxygen in the soil, whereas in the reduced condition when there will be less oxygen and more carbon dioxide specifics specifically in the water logged condition, there will be more carbon dioxide. So, as result of that there will be reduced forms which are present in these reduced conditions.

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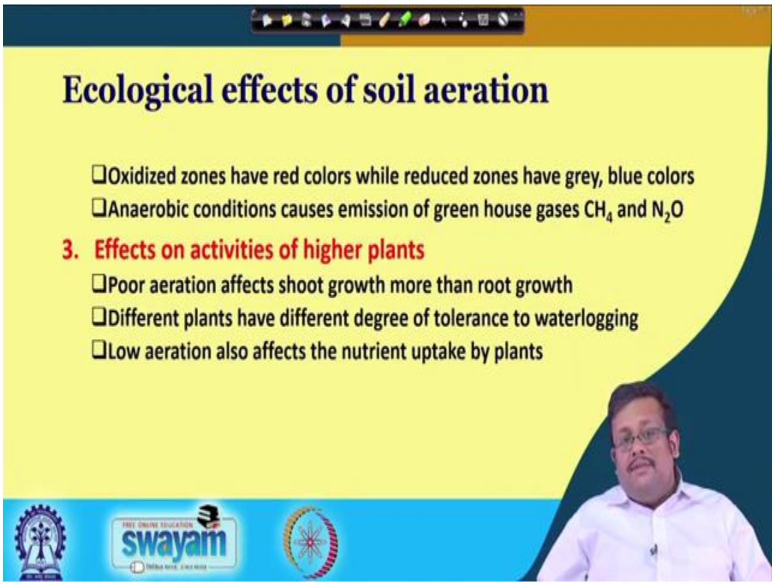

So, what are other important factors are, remember that oxidized zones have red color while reduced zones have gray blue colour ; and these are characteristic features of water saturated clay conditions. And remember that anaerobic conditions causes emission of greenhouse gases like methane and nitrous oxides. And effects on activities of higher plants, remember that poor aeration affects shoot growth more than the root growth, but different plants have different degree of tolerance for the water logging.

Because, as you can see in the rice field rice can withstand a, you know, water logging condition whereas most of the most of the field crops cannot withstand water logging condition, and also low aeration affects the nutrient uptake by the plants. So, these are effects of ecological effects of soil aeration which, you know, shows a clear impact on the activities and for the growth of different higher plants.

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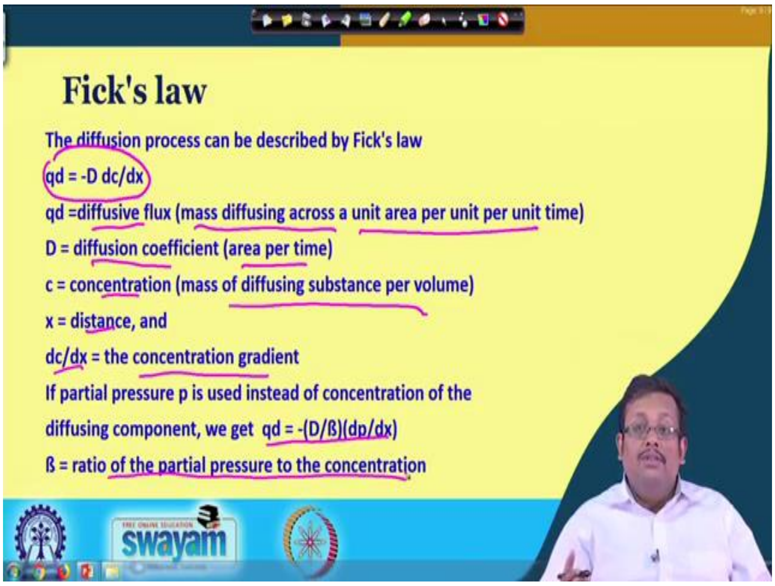

So, let us go to the next slide and see ok. So, one of the more major important law which governs the diffusion of gases in soil is Fick's law. So, we have to learn the Fick's law and in next lecture of this week will be talking about different we know problem solving different-different problems and we will be solving the problems using Fick's law of diffusion.

So, let us discuss about the Fick's law of diffusion. Well, you know the diffusion process in the soil can be described by Fick's law. Generally the form of Fick's law is qd equal to this minus D into dc over the dx. So, where qd is basically diffusive flux which is mass diffusing across unit area per unit time, in case of D it is a diffusion coefficient that is area per time, C is a concentration which is mass of diffusing substance per volume, x is the distance and dc over dx is the concentration gradient. And if partial pressure p is used instead of concentration of the diffusing component, we get this formula that is qd equal to minus D over beta into dp by dx. So, beta is basically the ratio of the partial pressure to the concentration. So, we have already discussed what is partial pressure in the last lecture? So, I will be going further I am not going to discuss it in details. So, this is the general form of Fick's law. And let us see; what are the further modifications of Fick's law?

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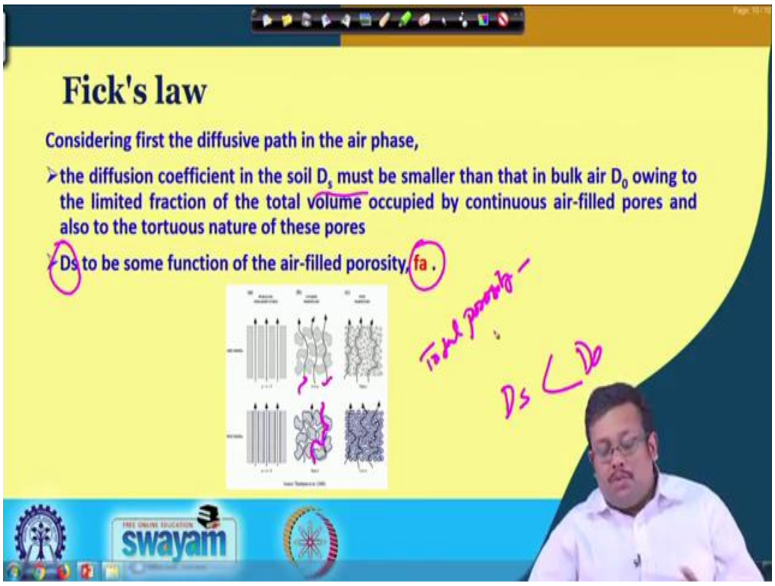

So, you know that considering first diffusive part in the air phase, I mean, if you consider the first the diffusive path in the air phase, the diffusion coefficient which in the Fick's law that is Ds must be it must be smaller than that of the bulk air D 0, owing to the limited fraction of the total volume occupied by the continuous air filled pored and also the tortuous nature of these pores. So, what does it mean? So, basically you can see that according to the Fick's law that the diffusion coefficient Ds must be smaller than that of the diffusion coefficient of D 0, that is the diffusion coefficient in the air in the bulk air.

So, why is that, because in the soil the diffusion is getting diffusion is not very simple as that in case of a bulk air. Because, in case of soil, some pores space are filled with, we know, some pores the total volume is occupied by the continuous air filled pores, because some pores will be filled by air and some pores will be filled by water. And also there will be tortuous nature of these pores. So, as you can see here these are coarse particles in any case of soil.

So, the path of diffusion is not very simple not very stretches just like here. So, this is called tortuous nature of diffusion so, tortuous pathway of diffusion. So, as a result of this, as a result of this phenomena, this Ds or diffusion coefficient in the soil has to be a function of the air filled porosity air filled porosity. Now what is air filled porosity? You know the total porosity. So, if you subtract the volume, we know, the volume of the pores which are occupied by the air from the total pore space, we will get the air filled porosity which we denote by fa.

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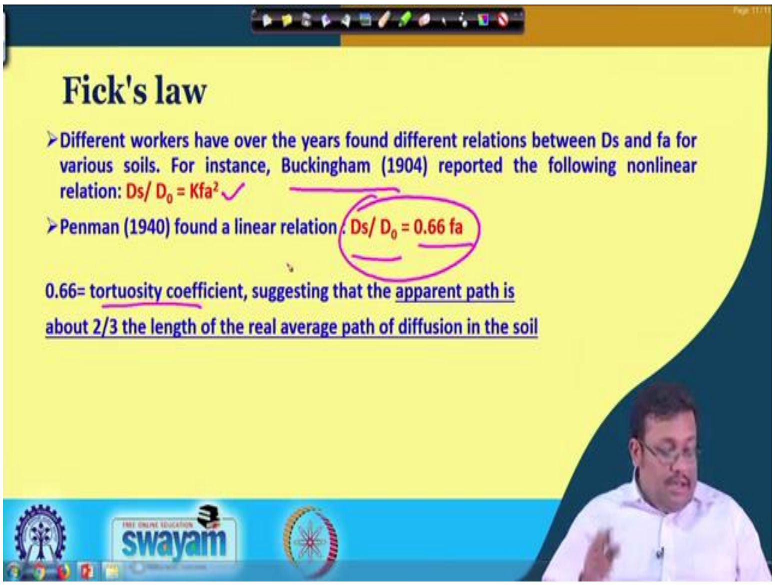

Now, this is this fa is very much important because, different workers have, you know ,have over the worker have over the years found different relation between these Ds and the fa between various soils. For instance, Buckingham in 1904 reported the following non-linear relation that is Ds over D0 equal to K fa square and this K is basically constant. So, Penman further modified and found a linear relation that is Ds over D0 equal to 0.66 fa. So, that basically means this 0.66 is basically tortuosity coefficient suggesting that apparent path is about two third length of the real average path of the diffusion in the soil.

So, this is very important formula please remember this formula, because this will be used for solving certain problems in the next lecture of our in the next tutorial.

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So, we have covered this Fick's law of diffusion and this is the reference, the nature and properties of soil by Nyle C Brady and Ray R Weil and so we have covered the all the major aspects of the soils aeration. And so, we are wrapping up the soil aeration chapter. So, let us go to another major important parameter that is soil temperature. This is the very important soil physical parameter.

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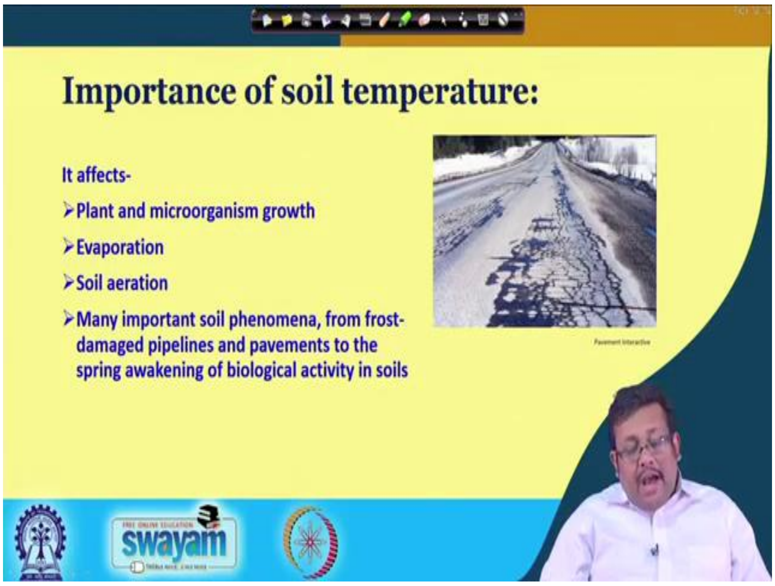

Now, what is the importance of soil temperature? Well, because, you know, soil temperature is very important because it affects plant and microorganisms growth, it also affects evaporation it affect soil aeration and many important soil phenomena, from forest damage pipelines, and pavements to the spring awakening of biological activities in soil is basically governed by the soil temperature. So, it is a very very important soil, you know, physical parameter or I would say it is a very important soil physical property.

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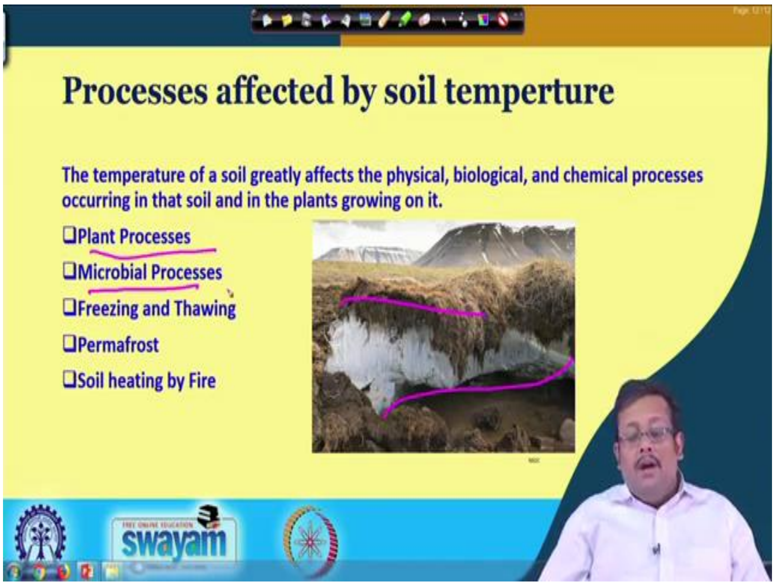

So, what are the processes that affected by soil temperature. So, the temperature of soil greatly affects the physical, biological and chemical process occurring in that soil and in the plants growing on it. Because, the different plant process, the plants are able to extract the water and nutrient in a specific range of temperature we will discuss in the next slide. And also microbial, the millions and billions of microorganisms which are present in the soil they are active in specific range of soil temperature.

They cannot be active beyond a certain range of temperature so, that is also important. Freezing and thawing, freezing and thawing is very important as you can see in this picture this is called a permafrost condition, we will discuss this later. Now, in the permafrost condition, considerable portion of the soil remains frozen. And this is basically you can see in the Tundra region of or in the hill in the mountainous region.

So, most of the part of the year you will see that these soils are, you know, are frozen remain frozen. So, these are called the permafrost condition and, you know, soil heating by fire is also very important process which affect which are governed by soil temperature. So, again these plant process different plant process that and the nutrient and water uptake by plants, and their microbial processes you will see that different types of microorganisms are present in different conditions. You see in the compost pit, there will be specific types of microbes, because they can they can withstand a specific range of temperature. So, all these processes are very much important from the soil as well as plant growth point of view. And these all are, you know, governed by the soil temperature or the variation in soil temperature.

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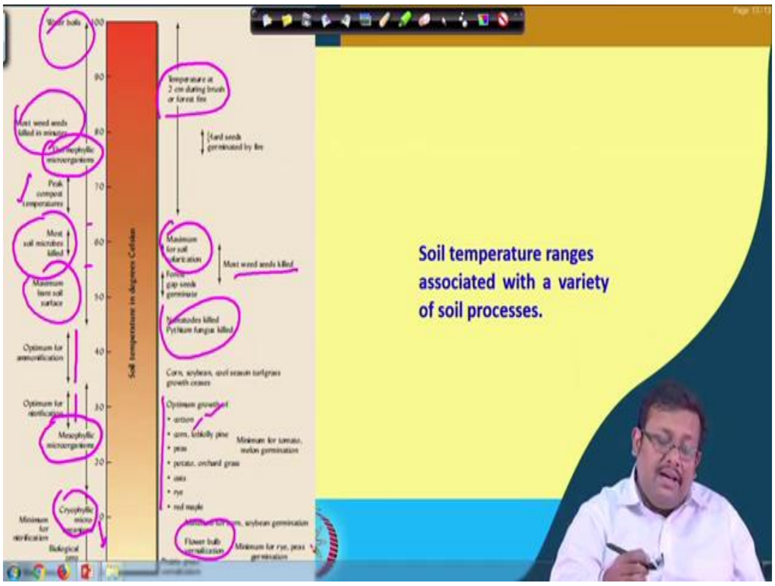

So, let us go head and see; what are the different ranges which are associated with a variety of soil processes? So, this is a very informative slide. So, let us start from the bottom. So, we can see that this in degree centigrade; obviously, this scale is in the degree centigrade. So, below 10 degree centigrade, there will be almost zero biological, we know, almost zero biological actions; so above 10 to.

So, the cryophilic microorganisms will remain in this temperature range and below and from 10 to 20 or 20 to 30, this range I would say from 15 to 35 you will see mesophilic microorganism will remain in the soil. And obviously, remember that this 30 to 35 degree centigrade range is optimum for nitrification which is one of the important nitrogen transformation process which we will discuss later on.

And remember that below temperature at the below 0 degree centigrade temperature there will be minimum biological activity and as a result of the minimum biological activity there will be minimum nitrification. And nitrification is required for the growth of the plant because, plant requires nitrate for their growth and this nitrate can be generated through the nitrification process, and obviously, ammonification which is another important process of nitrogen transformation. That occurs within the range from 35 to 40 degree centigrade.

And also you see from 45 degree to 100 degree, you will see the thermophilic microorganisms are mostly prevalent because they are, they love higher temperature for their growth. And you will see that, we know, maximum bare soil surface in the maximum bare soil surface, you will see the temperature range around 50 degree centigrade, and around from 55 to 65 degree centigrade in this range you see the most of the soil microorganisms are getting killed because of high soil temperature.

Only those microorganisms which are present in the compost pit, compost is an important soil manure we will discuss that later on. So, in the compost pit you will see some microorganisms are present and these microorganisms are thermophilic microorganisms they can only sustain in this higher temperature range. And above 80 degree you will see most weed seeds killed in the, you know, in minutes and obviously at 100 degree centigrade the water will boils. And also this 60 to around 60 to 100 degree centigrade you will see the temperature at 2 centimeter during the brush or forest, you know, brush or forest fire is in case of brush or forest fire you will see the temperature will vary in this region obviously. And also this temperature region that is 55 to around 60 it will be maximum for soil solarization.

So, most weed seeds killed in this region around 55 to 60. And, we know, nematodes get killed and pythium fungus get killed around 45 to 40 degree centigrade temperature. And for germination for most of the crops optimum growth of the most of the crops, you will see it grows in the range from 10 degree to around 30 degree centigrade. So, most of the crops optimum growth of cotton and, you know, corn, peas, potatoes, grass, oats, rye, rest everything can be grown most of them are grown optimally in this temperature region. And below the 10 degree centigrade you will see flower bud vernalization. So, what is vernalization will discuss in the next slide and also these are minimum for rye peas and rice and peas germination.

So, you see that the temperature soil temperature is very very critical not only for the growth of the crop, but also for the growth of the microorganisms and their and different nutrient transformation process, because all those nutrient transformation processes depends on microbial activity. So, if the microbial activity is low at a certain temperature obviously, all the microbial mediated nutrient transfer process transformation processes also get, we know, their rate also getting lower down.

So, this is very important slide. So, please remember this temperature ranges and we will discuss, you know, different different implication of the soil temperature ranges in in coming lecturers. So, I hope that this slide is informative to you.

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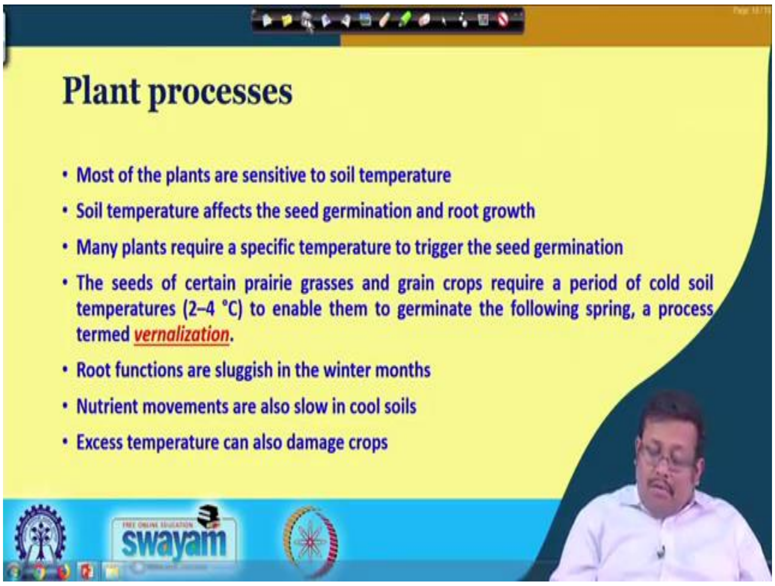

So, let us goes to let us go to the plant process. What are the important plant process? So, most of the plants are sensitive to soil temperature and remember that soil temperature affects the seed germination and the root growth. Seed will not germinate below a certain temperature or above a certain temperature. So, many plants require a specific temperature to trigger the seed germination; and remember what is vernalization. We talked about the vernalization in the last slide. So, the seeds of certain prairie grasses and grain crops require a period of cold soil temperature which varies from 2 to 4 degree centigrade to enable them to germinate in the following spring.

So, this process is called vernalization. And remember that root functions are sluggish in the winter months and nutrient movements are also so in cool soils and excess temperature can also damage the roots. So, for most of the field crops a generally temperature range from 15 to 35 degree centigrade is considered optimum for their growth. Some crops require somewhat higher temperature or somewhat lower temperature.

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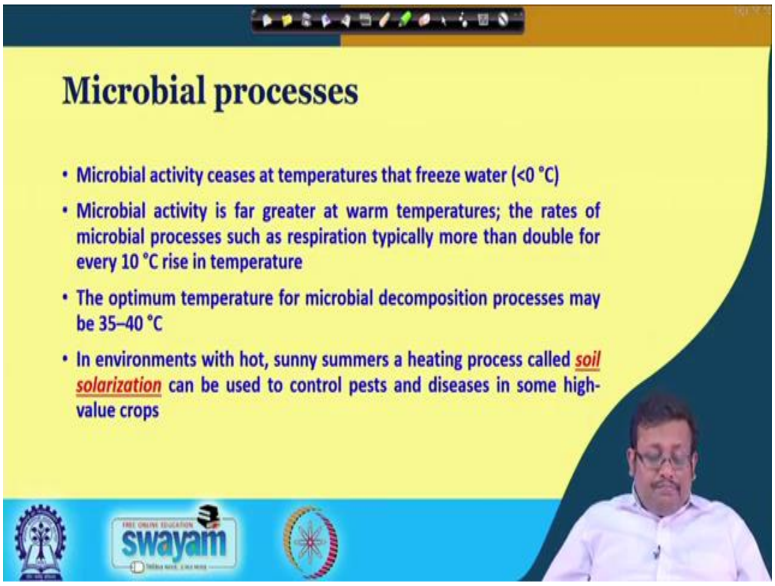

So, so, we have discussed the plant processes. Let us go to the next slide and see; what are the important microbial process. So, the microbial activity ceases the temperature that freezes water we have already seen that less than 0 degree centigrade. And microbial activities is far greater at warm temperature, and the rates of microbial processes such as respiration typically more than double for every 10 degrees centigrade rise in temperature. And the optimum temperature for microbial decomposition process maybe around 35 to 40 degree centigrade.

Remember that whatever, you know, remains dead in the soil and we are throwing any dead bodies into the soil, that need to be decomposed. So, that, we know, the nutrients and other organic matter can convert it to other beneficial forms.

Now, this optimum temperature for microbial decomposition process is 35 to 40 degree centigrade. So, if it is less than a certain temperature you will see that accumulation of more organic matter. So, that is why you will see in the cooler hilly region, you will see there will be accumulation of more organic matter or in another words lower rate of decomposition of organic matter.

So, in environments with hot and sunny summers and a heating process called solarization can be used to control pests and diseases in some high value crops. We have already seen the soil solarization in the last slide.

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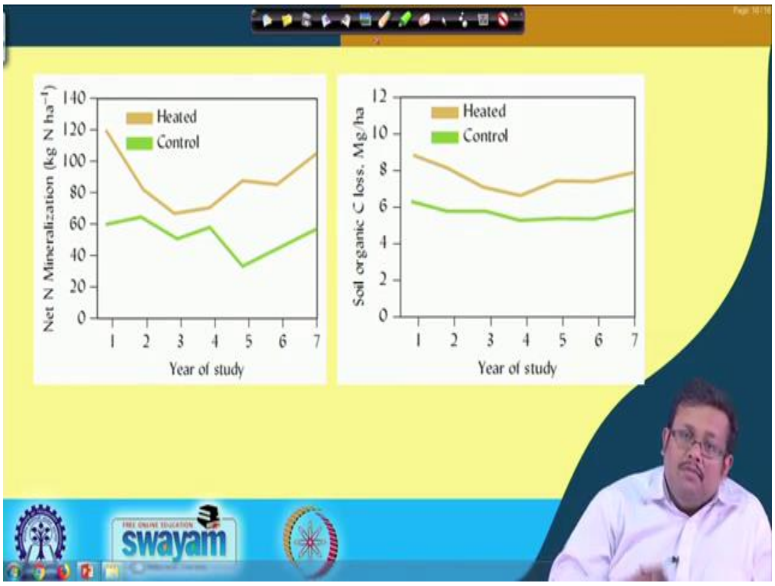

So, you see that what is the impact of temperature in net nitrogen mineralization and soil organic carbon losses? So, if you can see in this slide it is clear that at any given point of time, the higher the temperature obviously the nitrogen net mineralizing rate is higher, the similar the same thing is true also for soil organic carbon loss. So, that is how soil temperature affects not only the nitrogen dynamics, but also the carbon dynamics in the soil as well as their movement from soil to atmosphere.

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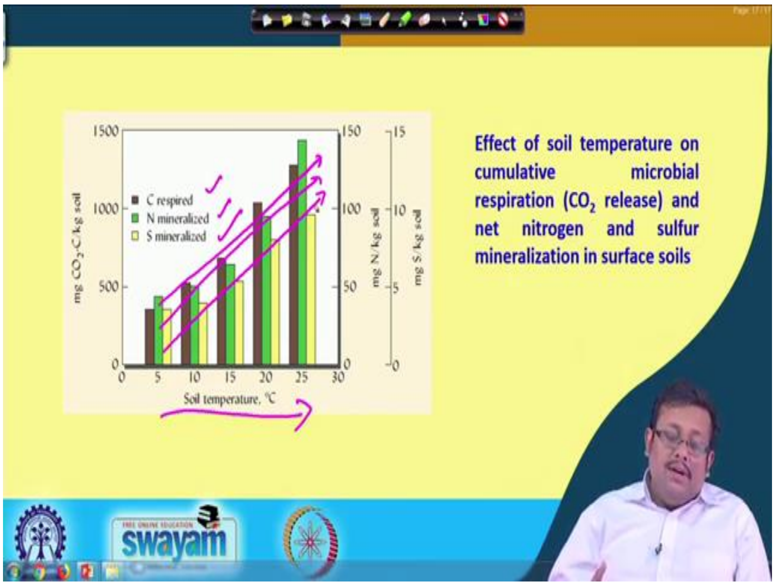

So, what are the effects on you can see also in this graph that, we are putting the soil temperature in degree centigrade from 0 to 30 degree centigrade. And we are seeing that, you know, different carbon, you know, different frames of carbon respired, nitrogen mineralization and sulphur mineralization. So, you can see that as the temperature increase obviously all three processes are increasing this carbon. The amount of carbon respired is continuously increasing from 0 degree to 30 degree centigrade, nitrogen mineralization is also increasing from 0 to 30 degree centigrade

So, likewise the sulphur also get increasing mineralized from 0 degree centigrade to 30 degree centigrade. So, this shows the effect of soil temperature and cumulative microbial respiration. These are basically microbial respiration or carbon dioxide released and net nitrogen and sulphur mineralization in surface soil. So, basically as the temperature increases, the microbial respiration or carbon dioxide release also increases. Totally carbon dioxide release, but also associated processes like nitrogen mineralization and sulphur mineralization also increases.

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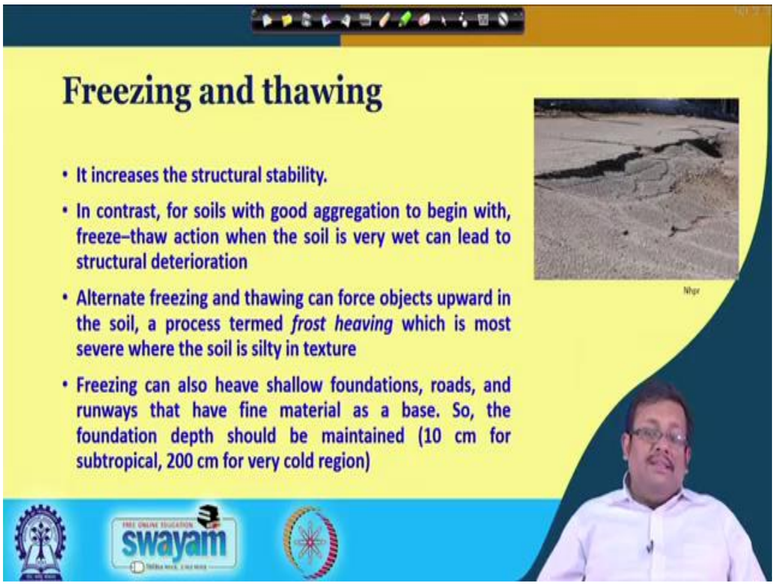

So, what is freezing and thawing? Now remember that the freezing and thawing increases the structural stability. However, for soils with good aggregation to begin with, freeze thaw action when the soil is very wet can lead to structural deterioration. An alternate freezing and thawing can force objects upward into the soil a process called frost heaving, we will see what is frost heaving in the next slide which is most severe when the soil is silty in nature.

And freezing also can have shallow foundation, sorry, freezing also can heave the shallow foundation, roads and runaways, you know, runaways that have, you know, fine material as a base. So, the foundation depth should be maintained that is 10 centimeter for subtropical and 200 centimeter for very cold regions.

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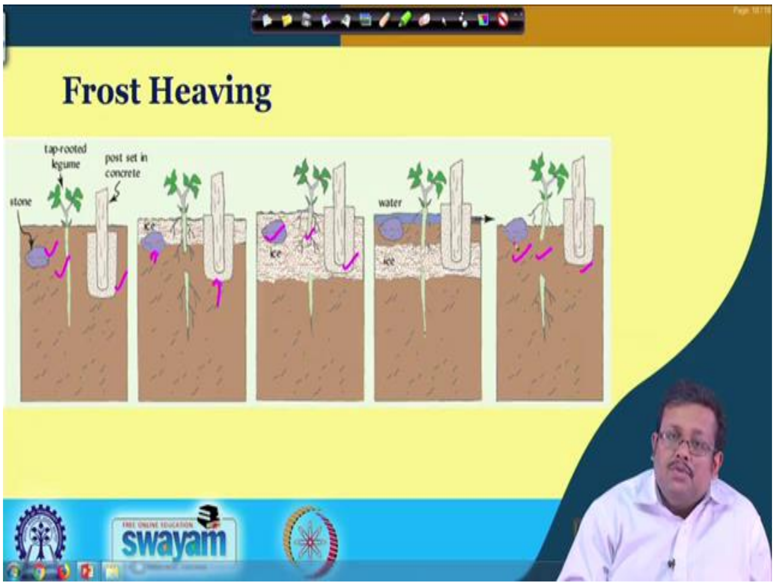

So, let us see what is frost heaving? So, you can see is here in this slide at the beginning there is a tap rooted legume here. So, we are also seeing a stone at a certain depth in the soil and also there is a post set at concrete at certain depth. So, as the ice begins to develop, there will be, you know, the ice lines is, you know, continuous to form and as a result you will see there is slightly movement upward slightly upward movement of this posts as well as this, we know, the stone.

And as ice lines continues to grow, the relative position of this post, ice and this, we know, of this plant is, we know, increased. And after certain period of time, when the ice melts, the melting starts from the top obviously, but as a result of that as a result of the total melting after the total melting of the ice you will see there will be a relative displacement upward displacement of all the objects starting from this post and this plant as well as this stone.

So, this is called frost heaving and this is very very dangerous for any engineering construction. So, that is why it has to be very very you may need to take care, you know, you need to consider this very carefully while we are building any engineering structure.

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So, what is permafrost? We talk about permafrost a little bit. So, the thawing of arctic permafrost the permafrost we discuss, permafrost is a condition where the soil remains frozen for a considerable part of the year. And remember that the thawing of this arctic permafrost is expected to further accelerate global warming. As decomposition of organic matter, you know, organic materials long trap in the frozen layers of histels. Histels mean histosol and gelisols. It is a combination of histosol and gelisol.

So, in this condition, obviously this, thawing of this arctic permafrost will release vast quantities of carbon dioxide into the atmosphere. So, generally this permafrost in this permafrost condition, we know, they preserve the organic carbon into the earth. They helps in, they help in basically carbon sequestration. However, due to the thawing of arctic permafrost, a huge amount of this sequestered carbon in the form of organic matter get decomposed. And as a result, it produces these different types of greenhouse gases ultimately which leads towards the global warming.

So, in this lecture we have discussed some basic aspects of soil aeration, what are the important factors of soil aeration. And then, we discuss about different aspects of soil temperature. And so, let us wrap up here and we will try to finish the soil temperature in our next lecture.

Thank you.