Soil Fertility and Fertilizers
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Lecture 07
Soil Nitrogen for Plant Nutrition (Contd.)

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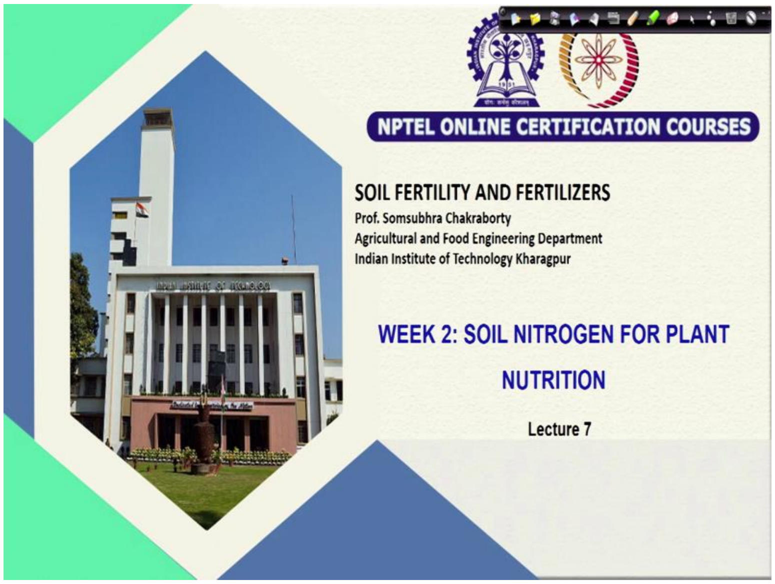

Welcome friends to the second lecture of week two of NPTEL online certification costs of Soil Fertility and Fertilizers. And in this week, we are talking about Soil Nitrogen for Plant Nutrition. So, in the first lecture of this week, we have already discussed about different forms of nitrogen and also we have discussed the mineralization process, immobilization process, and we have discussed the biological nitrogen fixation and the types of biological nitrogen fixation we have discussed.

And also we have seen the overview of nitrogen soil nitrogen cycle and also we have discussed the importance of C:N ratio in controlling the immobilization and mineralization in the soil. So, in this second lecture of week two or Lecture Number 7, we are going to cover these following concepts.

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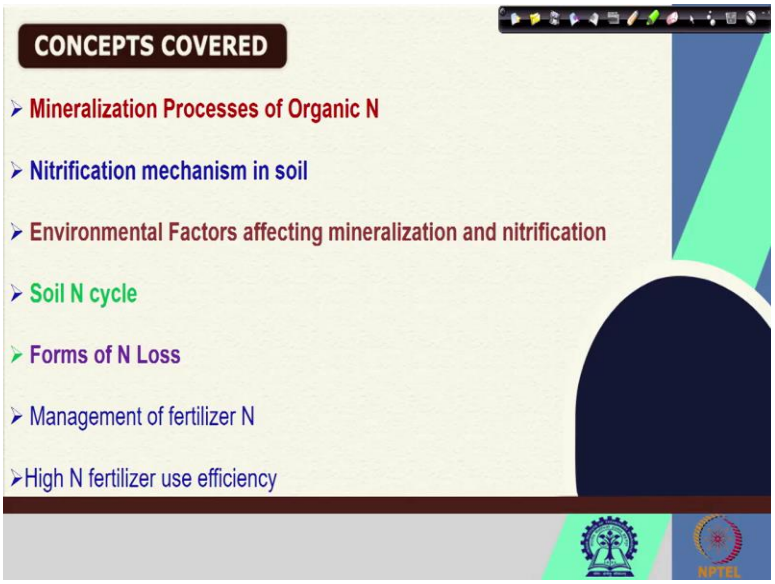

So, we are going to discuss in details about the mineralization processes of organic nitrogen and then we are going to discuss the nitrification mechanism in soil and then we are going to discuss the environmental factors affecting mineralization and nitrification then soil nitrogen cycle, forms of nitrogen loss, management of fertilizer nitrogen and high nitrogen fertilizer use efficiency. So, all these different types of issues we are going to discuss in this lecture.

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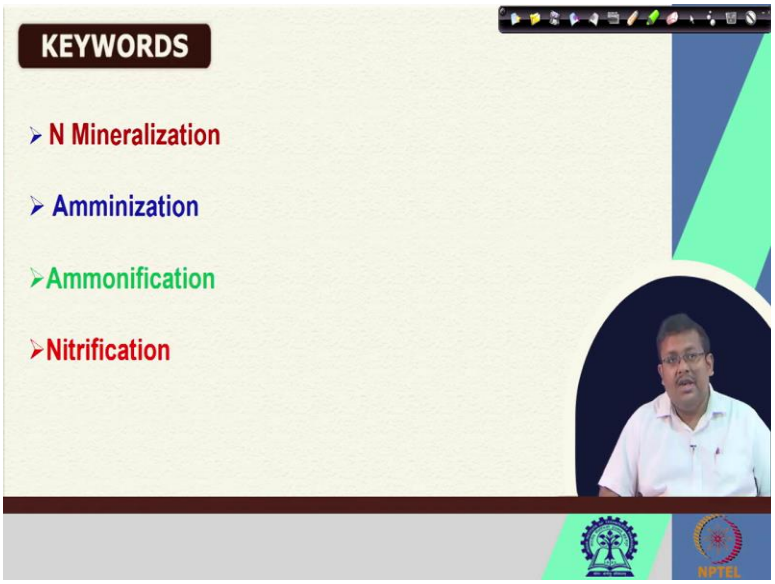

And these are some of the keywords which we are going to discuss nitrogen mineralization, amminization, ammonification and nitrification. So, these are some important process, we are going to discuss in details.

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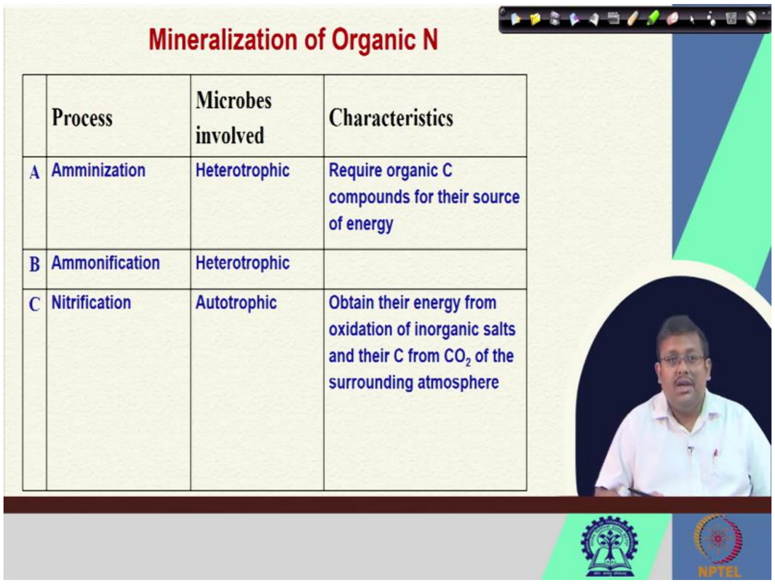

So, if we see the important nitrogen processes, soil related processes as well as the types of microorganisms involved and their characteristics. We can have a detailed overview of these from this table. So, you can see here the first process is amminization process, what is amminization process, I will deal in detail. So, in this amminization process, the microbes are mainly heterotrophic microorganisms are involved.

And in this m amminization process, it requires organic carbon compounds for their source of energy. So, these microbes require organic carbon compounds for their source of energy. Second process is ammonification process, here also heterotrophic microorganisms are involved. And in the nitrification process, this is being governed by autotrophic microorganisms and these autotrophic microorganisms obtain their energy from oxidation of inorganic salts and their carbon from carbon dioxide of the surrounding atmosphere. So, these are some the process and these are the microbes or microorganisms which are involved in these processes.

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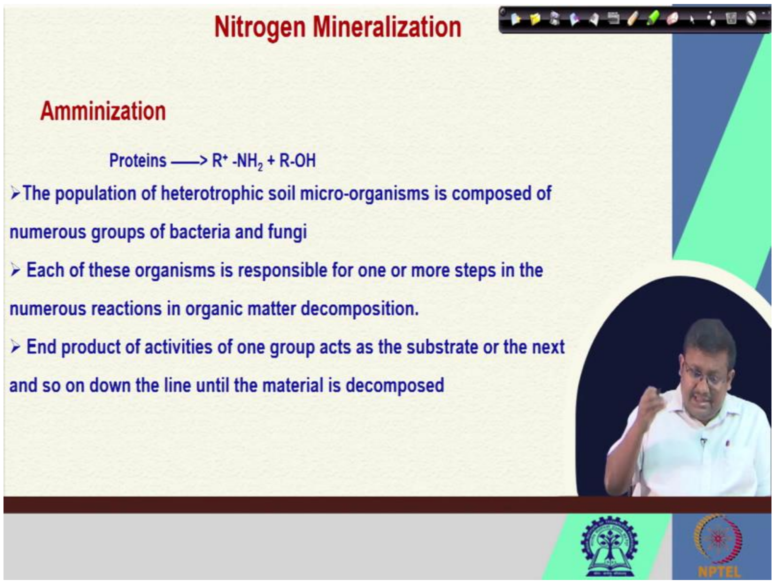

Now, let us start with the amminization process. The amminization process is basically conversion of protein to these compounds with amine groups. So, the population of heterotrophic soil microorganisms is basically composed of numerous groups of bacteria and fungi. And each of these organisms is responsible for one or more steps of the numerous reactions in the organic matter decomposition process.

And end product of activities of one group acts as a substrate or the next as so on down the line until the material is decomposed. So, basically what happens different groups of bacteria and fungi are involved in this decomposition process. So, one groups decompose and one group mean, governs one process and the end product from that reaction acts as a substrate for the next group and then they start from there and then convert this substrate to other compounds. And ultimately, we reach to the final decomposition process.

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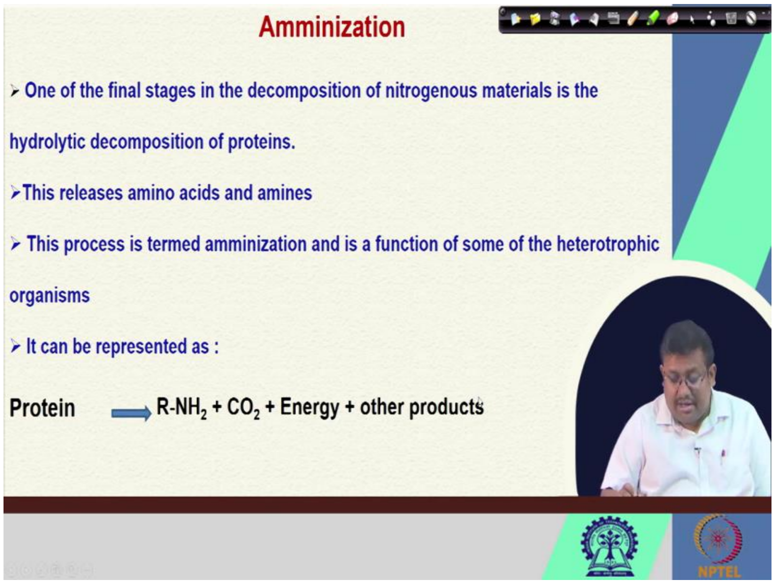

So, this amminization, so one of the final stages in this decomposition of nitrogenous material is the hydrolytic decomposition of proteins. So, we can see this amminization process release amino acids and amines. So, this process is termed amminization and it is a function of some of the heterotrophic organisms. So, it can be represented by this equation, so protein R-NH2 plus CO2 plus energy and other products. So, ultimately from this protein, you can see there is a decomposition of protein ultimately to produce these amines, carbon dioxide energy and other products. So, you can consider this a first step of decomposition process.

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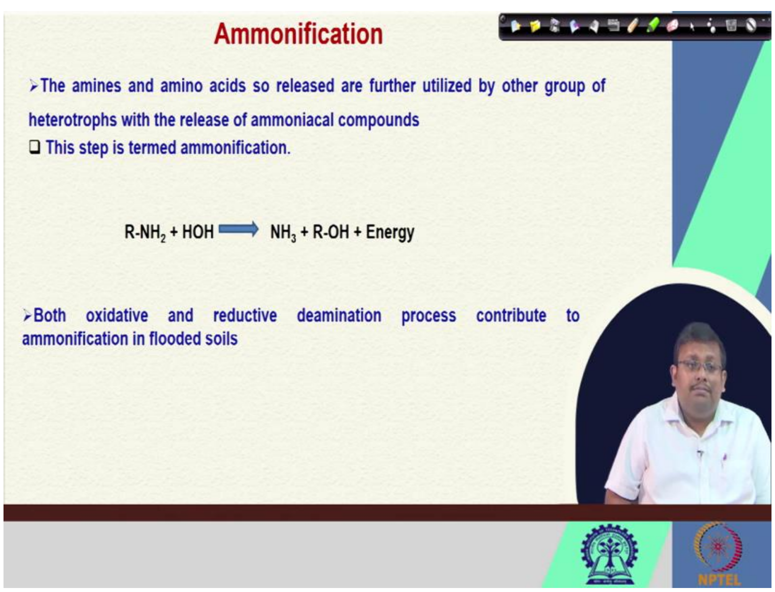

Now, the second step is the ammonification process. So, these amines are amino acids, so, released that farther utilized by other groups of heterotrophs with the release of ammoniacal compounds. So, this step is termed ammonification. So, you can see here R-NH2 and here it is reacting with the water, ultimately it is producing these ammonia and then alcohol and energy.

So, both oxidative and reductive deamination process contribute to ammonification in flooded soils. So, basically in short the conversion of amino acids to ammoniacal compounds is basically known as the ammonification process and this ammonification process is mediated by heterotrophs.

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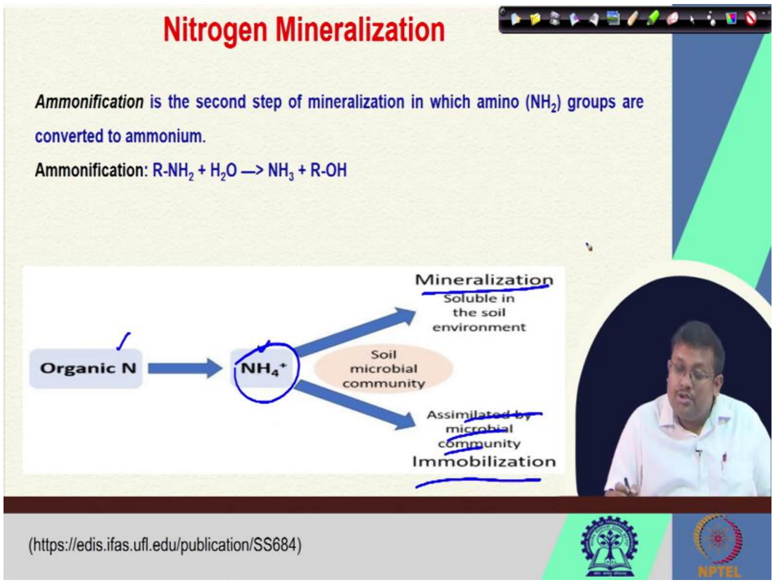

Now, we know that ammonification is the second step of mineralization in which the amino groups are converted into ammonium. So, we can see here first we start with organic nitrogen and its get converted into ammonium through the ammonification process. So, this is the second step, the first step is amminization and then ammonification. And this ammonium ion is basically utilized by other microorganisms to get mineralized.

So, ultimately this ammonium ion gets converted into nitrate, which we are going to discuss. And also some amount of this ammonium ion gets also assimilated by microbial community through the process of immobilization. So, this ammonium which is formed due to mineralization or ammonification can also goes for further mineralization and goes to nitrate or it can be assimilated by different microorganisms or crops. So, I hope now, this ammonification process is clear.

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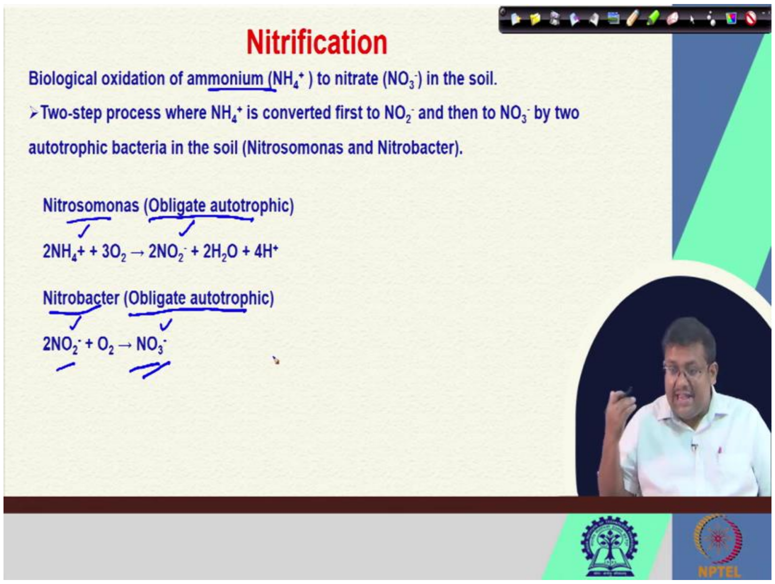

Now, biological oxidation of ammonium to nitrate in the soil is known as nitrification. This is one of the major step of nitrogen dynamics in soil. So, this two step process of nitrification is basically accomplished by conversion of ammonium ion to nitrate first and then from nitrate to nitrite first and from nitrite to nitrate by two groups of autotrophic bacteria in the soil.

So, here you can see the first step is conversion of ammonium ion to nitrite and the second step this nitrite gets converted to nitrate. So, the first conversion of ammonium to nitrate is basically mediated by Nitrosomonas which is obligate autotrophic microorganism, the second step that is conversion of nitrite to nitrate is governed by another obligate autotrophic bacteria called Nitrobacter.

So, these two organisms play an important role for conversion of ammonium ion to ultimately to nitrate and this process of conversion of ammonium to nitrate is known as nitrification process. So, nitrification is very important process through which these ammonium gets converted into nitrate because most of the crops prefer these nitrate as an available nitrogen form. So, it is important that this ammonium which is formed due to ammonification process must be converted into this nitrate through this nitrification process.

So, this biological nitrogen, it is a biological oxidation process and these two, and one more important thing is this nitrate which is an intermediate step or intermediate product in this nitrification whole nitrification process. This is very short lived and it is toxic in nature for plant also, but fortunately, it is very short lived and gets converted to nitrate very fast. So, that is why there is no accumulation of nitrate in the soil, its get converted into nitrate very fast through the Nitrobacter organisms or bacteria.

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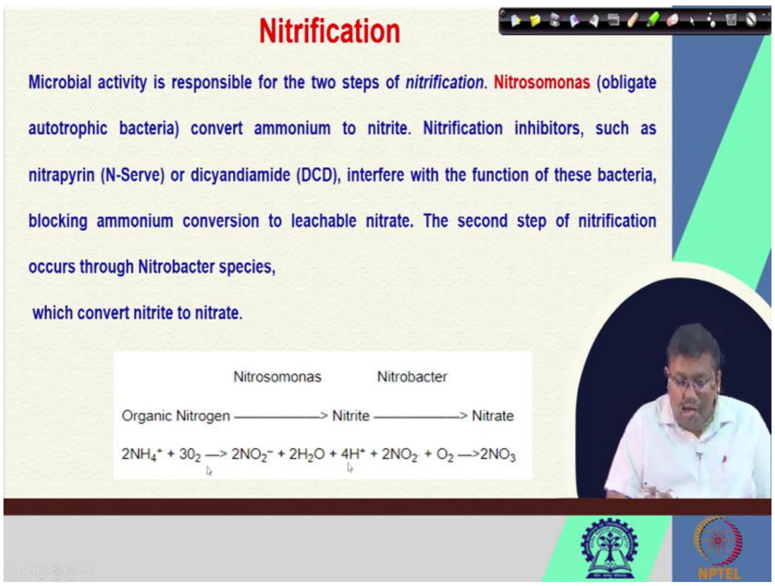

Now, it is clear to us that nitrification is a micro mediated process and Nitrosomonas basically helps in conversion of ammonium to nitrite and nitrobacter helps in conversion of nitrite to nitrate. Now, we will also see in our coming slides that the rapid nitrogen conversion to nitrate is sometime not desirable, because plant can uptake very few amount, I mean very small amount of available nitrate and rest of it gets lost from the soil through different process.

So, to arrest or to stop this rapid conversion of ammonium to nitrite, so that nitrate production gets us, nitrate production is reduced. So, we generally apply different types of nitrification inhibitors. What are these nitrification inhibitors? One of them is nitrapyrin, which is also known as N-serve, another one is dicyandiamide or DCD and these basically interfere with the function of these Nitrosomonas bacteria.

So, the conversion of ammonium to the nitrate gets hampered and as a result nitrate production will not be there. So, this is called nitrification inhibitors. So, here you can see the complete conversion, complete process of nitrification. So, you can see here it is the organic nitrogen (())(12:12) and then ultimately ammonium to Nitrosomonas to nitrite mediated by Nitrobacter to nitrate. So, these ammonium plus three molecules of oxygen ultimately converts into nitrite and then four protons and ultimately it gets oxidized to nitrate. So, this is the nitrification process. And you can see that this nitrite is an intermediate and very short lived, which gets immediately converted to nitrate.

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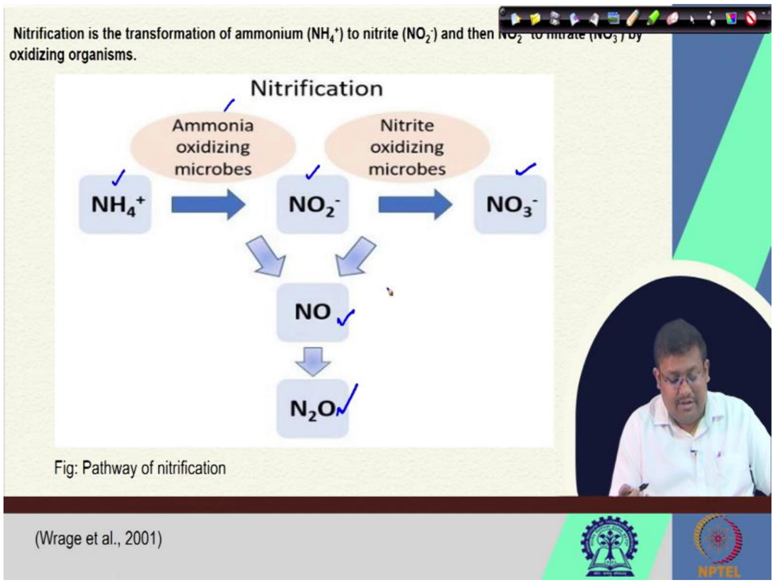

Now, nitrification we know that it is a transformation of ammonium to nitrate and then nitrite to nitrate it can be, this pathway of nitrification you can clearly see here. So, first there is an ammonium ion which is and then this is basically utilized by ammonia oxidizing microbes or Nitrosomonas to get converted into nitrite and then this nitrate gets converted into nitrate oxidizing microbes or Nitrobacter to nitrate. And from both these they can convert into nitric oxide gas and nitrous oxide gas and ultimately goes through the atmosphere also. So, this is showing the pathway of nitrification.

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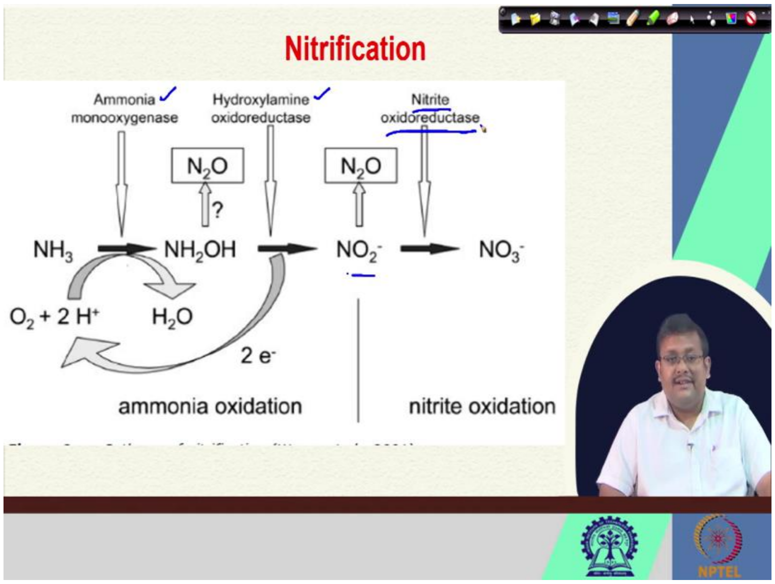

And also, we can see here that there are different types of enzymes which governs this conversion of, the different conversions in this nitrification process, we can see these ammonium to ammonium hydroxide conversion is basically governed by these ammonia mono oxygenase enzyme and then from these ammonium hydroxide to nitrite is being governed by these hydroxylamine oxidoreductase enzyme and this conversion of nitrite to nitrate is mediated by these nitrite oxidoreductase enzyme. So, not only it is this process is governed by microorganisms, but at the same time, these are also dependent on these different enzymes also.

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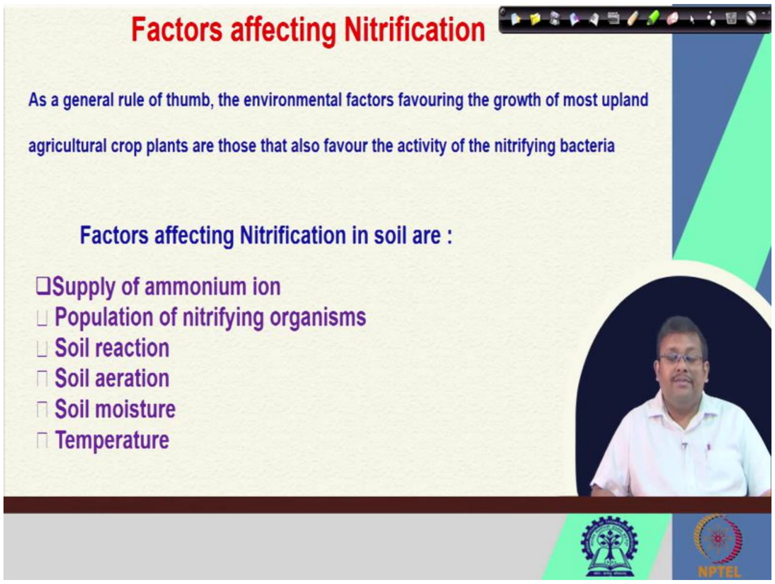

So, these are some of the factors which are affecting the nitrification in soil. First of all is supply of ammonium and then population of nitrifying organism, then soil reaction, soil aeration and then soil moisture, temperature these are all important for controlling these nitrification process in the soil.

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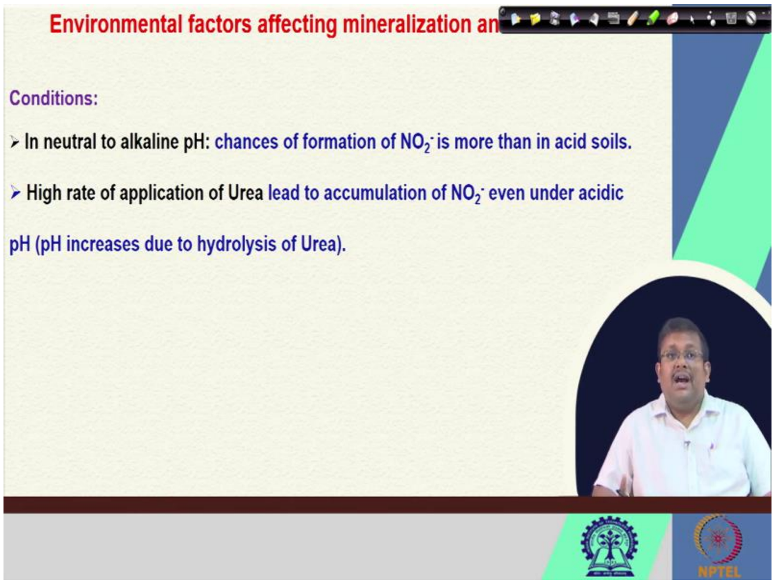

Now, in neutral to alkaline pH condition chances of formation of nitrate is more than in acid soil. So, in alkaline condition formation of nitrate the chance is more than in acid soil. And when we go for high rate of application of urea fertilizer that can result in the accumulation of nitrate even under acidic pH condition, because pH increases due to hydrolysis of urea, so when you apply this urea into acidic pH soil that can increase the pH by the hydrolysis of urea and ultimately that results in the accumulation of nitrate.

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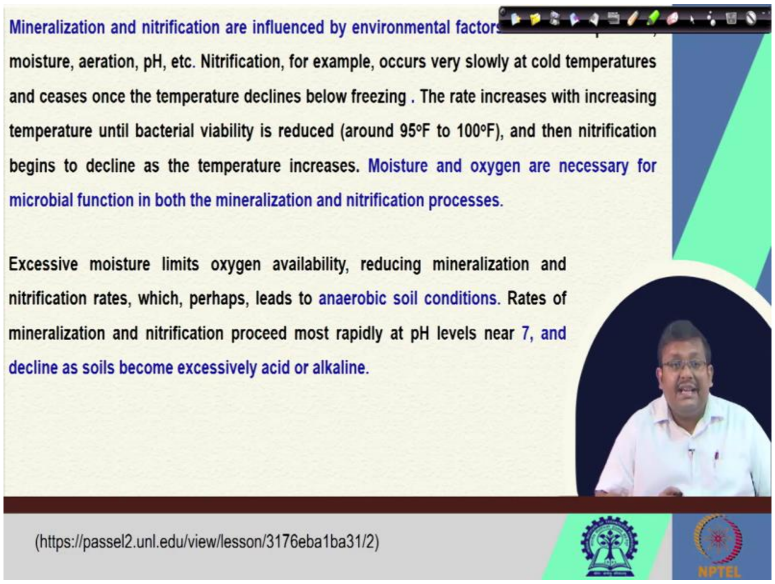

Now, mineralization and nitrification are also influenced by several factors like moisture, aeration, pH. So, for example, nitrification occurs very slowly at cold temperatures and ceases once the temperature declines below freezing, because the microorganisms the bacteria which are involved in this nitrification process, they are activities increase with the increase of temperature.

So, if the temperature goes below freezing, they become inactive and ultimately there is no conversion of one nitrogen form to another nitrogen form. The rate increases with increasing temperature until the bacterial viability is reduced, which is around 95 degree Fahrenheit to 100 degree Fahrenheit and then nitrification begins to decline as the temperature increases. So, there is also a certain threshold beyond which the nitrification also will go down.

Moisture and oxygen are also necessary for microbial function in both the mineralization as well as nitrification process. Remember that since these processes are mediated by microbes, we have to ensure that their growth condition proper growth conditions are maintained. Excessive moisture sometime limits oxygen availability, reducing this mineralization and nitrification rates because nitrification is an oxidation process.

So, when there is excessive moisture in the soil that will occupy the space of air ultimately reducing the oxygen availability and ultimately reducing this nitrification process. So, in this condition, this is called the anaerobic soil condition, this nitrification process will goes down, will go down. And rates of mineralization and nitrification proceed most rapidly at each pH near 7 and decline as the soil become excessively acid or alkaline because the microbes become inactive when the soil becomes excessively acidic or alkaline in nature.

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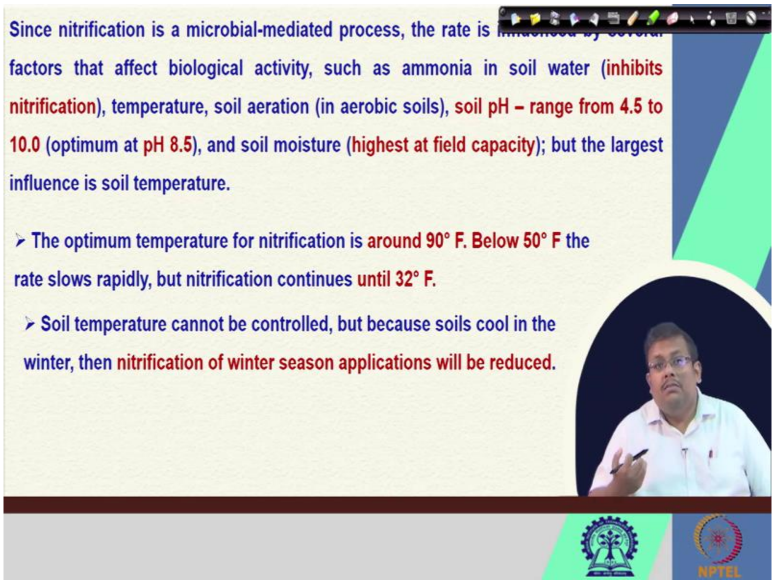

Also, since nitrification is a microbial mediated process, the rate is governed by factors that affect these biological activities such as ammonia in soil water, which inhibits the nitrification process, also temperature which we have already discussed, soil aeration in aerobic soil and soil pH generally ranges from 4.5 to 10. But, we have discussed that optimum pH is from 7.5 to 8.5 and of course, the soil moisture.

So, these nitrification is highest when the soil moisture is conducive for the growth of the microbes, but, the law among all these the highest influence or the largest influence can be seen from the temperature. So, the optimum temperature for nitrification is around 90 degree Fahrenheit, below 50 degree Fahrenheit, the rates slow rapidly and nitrification continues until 32 degree Fahrenheit.

So, soil temperature cannot be controlled, but because soil cools in the winter, the nitrification of winter season application will be reduced. So, basically the nitrification process slows down in the winter because soil becomes colder in winter. So, that is an implication of temperature in the nitrification process.

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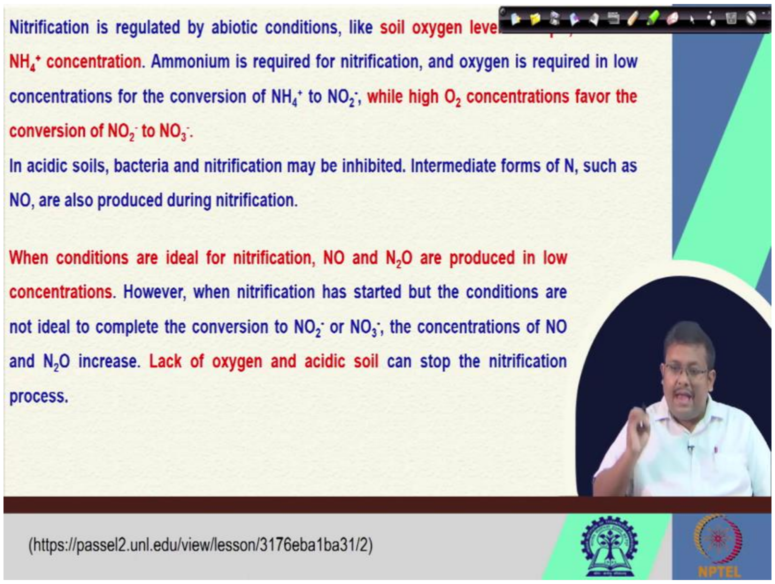

And also nitrification is governed by soil oxygen level, because it is an oxidation process and also the ammonium concentration. So, ammonium is required for nitrification because it is the starting point. And oxygen is required in low concentration for the conversion of ammonium to nitrate. However, for the conversion of nitrite to nitrate we require high amount of oxygen concentration, without oxygen there will be no conversion from nitrate to nitrate.

Now, in acidic soil bacteria nitrification may be inhibited and intermediate forms of nitrogen such as nitric oxides are also produced during the nitrification process. Now, when conditions are ideal for nitrification nitric oxides and nitrous oxides are produced in low concentration. However, when nitrification has started, but the conditions are not ideal to complete the conversion of nitrite to nitrate the concentration of these two gases increases.

So, lack of oxygen in an acidic soil can stop this nitrification process also. So, you should always keep in mind these factors while taking a decision regarding the nitrification process, because nitrification is a complex interplay of different environmental factors and microbes. And one should have a clear idea about this nitrification process so that maximum amount of nitrogen can be available to the plant otherwise there will be loss of nitrogen.

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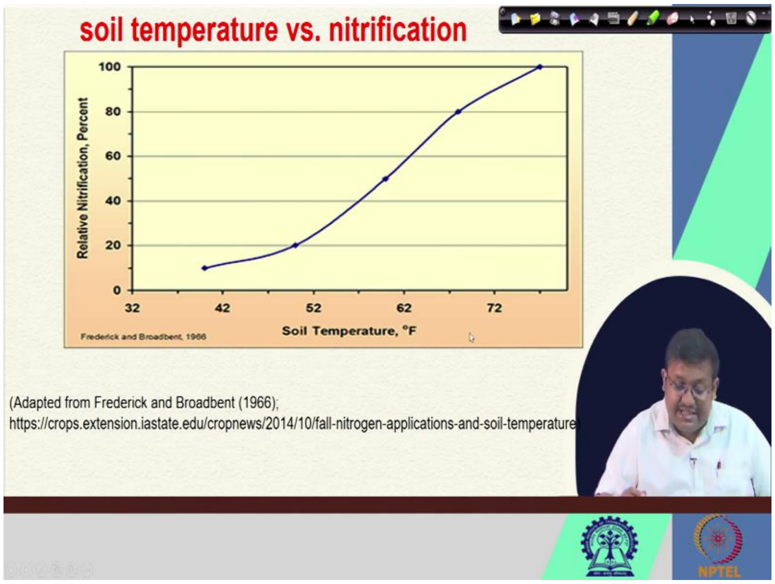

So, you can see in this graph, there is a relationship between the soil temperature and relative nitrification. So, as the soil temperature increases, the relative nitrification increases the percent of relative nitrification increases. So, that shows the importance of temperature in controlling this nitrification.

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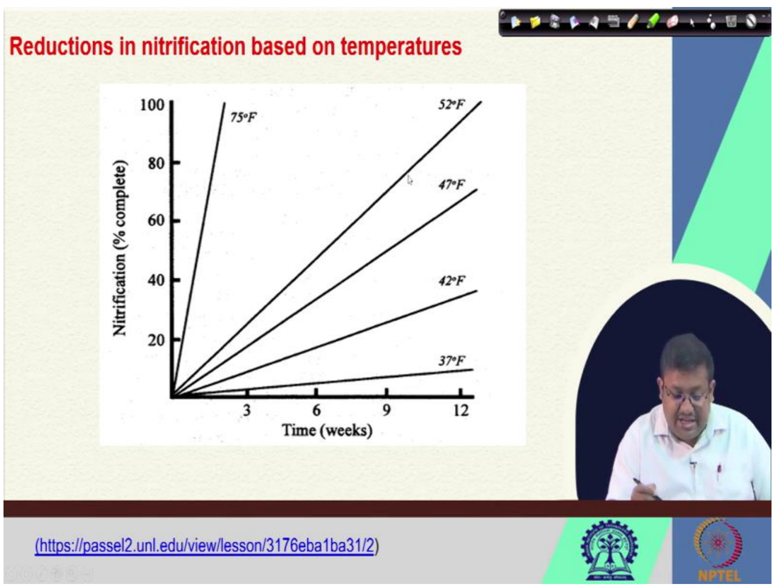

Also in this graph, you can see the importance of temperature. So, as the temperature increases, the nitrification process increases, the rate of nitrification increases. So, of course, when there is a very low temperature that reduces the nitrification process.

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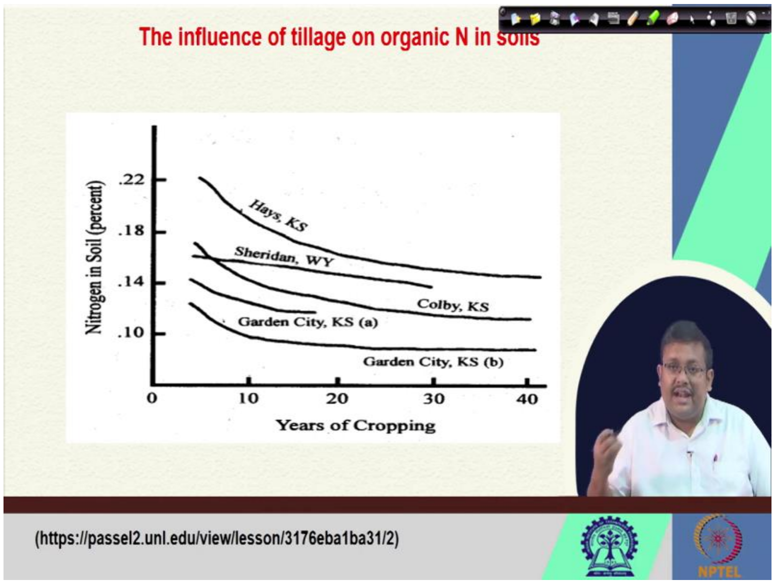

Also we can see that the influence of tillage on organic nitrogen in soil, so, of course, as we maintain the soil for long duration. So, of course, the nitrogen in soil will go down due to the tillage practices. So, when there is a tillage practices that influences the decomposition of nitrogen of organic matter and that creates the percent, that basically reduces the percent content of nitrogen in soil because of different types of decomposition process, because when there is a tillage practice that opens up the soil that helps in more oxidation of the organic compound and you know that nitrogen mainly present in organic form, 95 percent inorganic form and when there is an oxidation that will reduce the nitrogen content in the soil.

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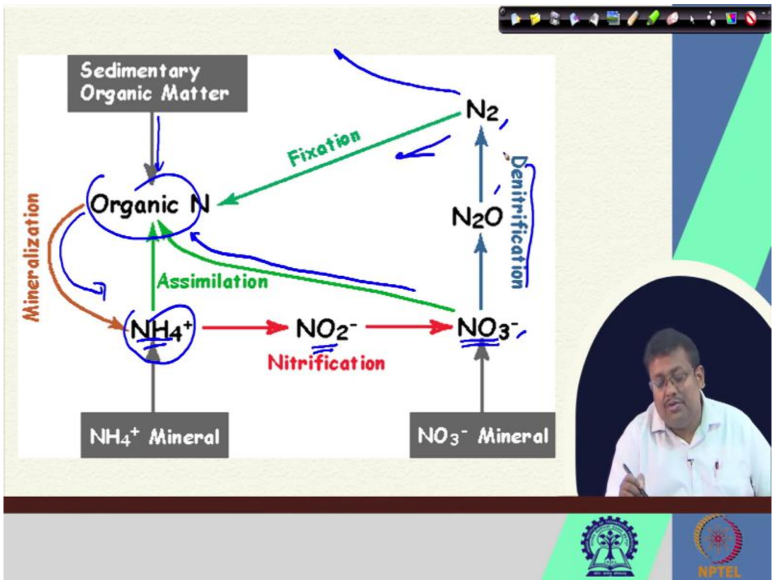

So, here we can see an overview of these different processes. So, you can see there is a sedimentary organic matter which ultimately goes to enrich this organic nitrogen, from organic nitrogen mineralization process will convert, this will results in this ammonium ion, these ammonium ion will go through nitrification process ultimately will produce these nitrate. And there are some ammonium containing mineral which will enclose these ammonium ion and there are some nitrate minerals also.

Anyway this nitrate will be assimilated by the plant and ultimately will convert again to organic nitrogen from this inorganic nitrate. And due to the denitrification process, the denitrification process generally occurs in the oxygen limiting condition that is anaerobic condition. So, in this anaerobic condition microbes utilize this nitrate and ultimately convert into these nitrogen gases and ultimately this nitrogen will go to the atmosphere and some amount of nitrogen will be again fixed to biological nitrogen fixation and ultimately goes to this organic nitrogen pool. So, this will show the conversion of different forms of nitrogen.

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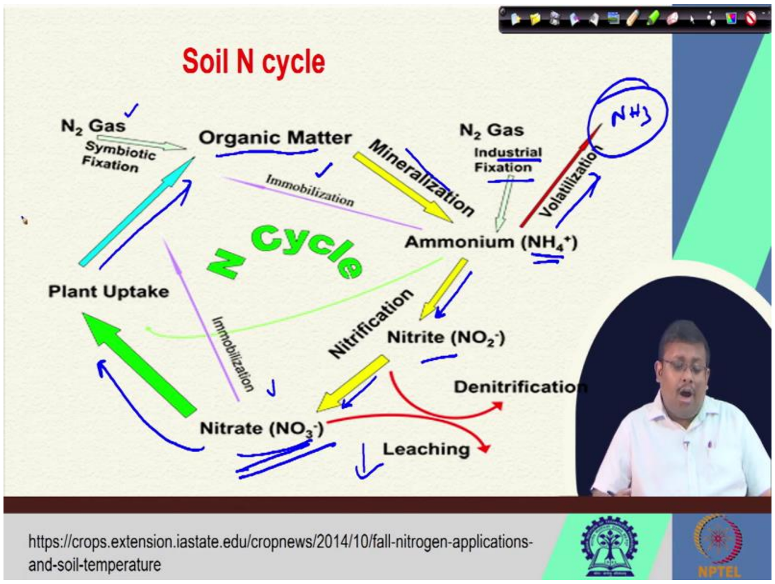

And this is a snapshot of the soil nitrogen cycle. You can see we have already discussed all these things. So, the nitrogen gas goes through the symbiotic nitrogen fixation ultimately goes to organic matter and this organic matter will be mineralized to form these ammonium ion, these ammonium ion will go through this nitrification process ultimately will produce these nitrite and nitrate, these nitrate will be up taken by the plant and when the plant dies it goes to the organic matter pool also.

So, and also the conversion of these ammonium to organic forms is a example of immobilization and immobilization also occurs from conversion of nitrate to these organic matter forms. And while this nitrite getting converted into nitrate denitrification process can release the nitrogen in the atmosphere and also these nitrates is also very soluble in water and thereby lost from the soil through the leaching process.

And ammonium ion depending on the soil pH gets also released into the atmosphere through ammonia gas and this is known as ammonia volatilization process. And this ammonium ion is also being contributed by different types of industrial fixation. So, this is showing the snapshot of soil nitrogen cycle.

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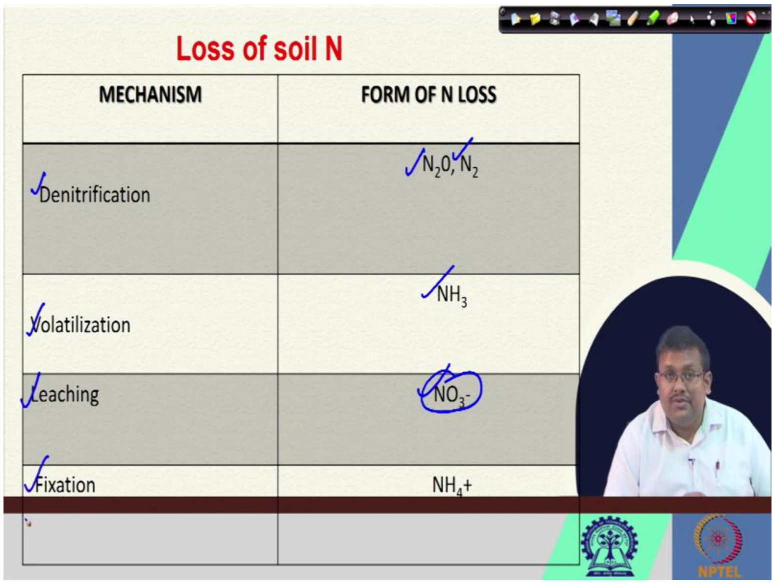

So, let us see what are the major forms of nitrogen losses in different mechanisms. So, we can see in case of denitrification process nitrogen mainly lost in the form of nitrous oxide and dinitrigen gas. In case of volatilization it is lost as ammonia gas. In case of leaching it is lost as nitrate because nitrate is highly soluble in water and fixation is another process through which the nitrogen gets lost. So, ammonium is lost through fixation process to different in different minerals which are present in the soil.

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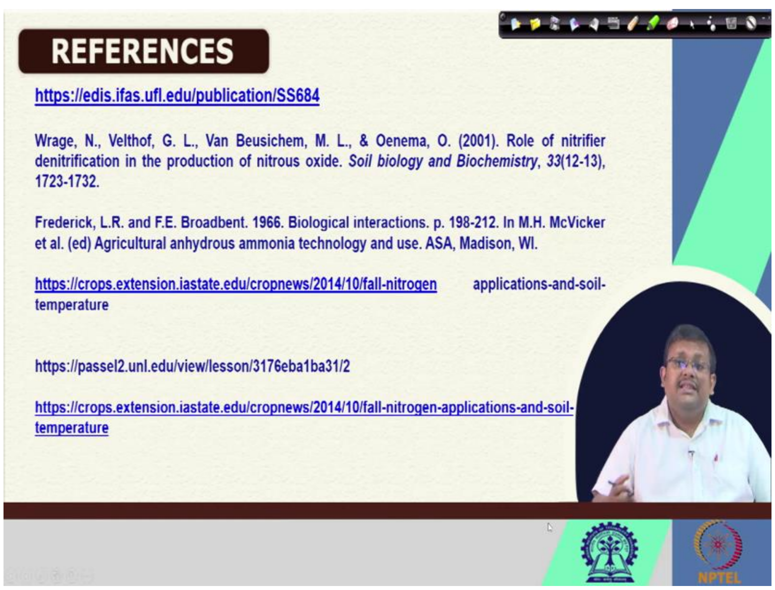

So, guys, these are the references of this lecture. And I hope that you have gained some insight to these soil nitrogen cycle and these related processes. We have discussed the important factors which govern this nitrification and let us start from here and we will discuss more about soil nitrogen dynamics in our upcoming lectures. Thank you.