Soil Science and Technology
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Lecture - 32
Soil N

Welcome friends to this new topic of the week 7 lectures and today we will be starting about, we will be starting Soil Nitrogen. We will discuss about different processes of soil nitrogen. So, let us start and let me show you what are the different concepts, we will be covering in this lecture.

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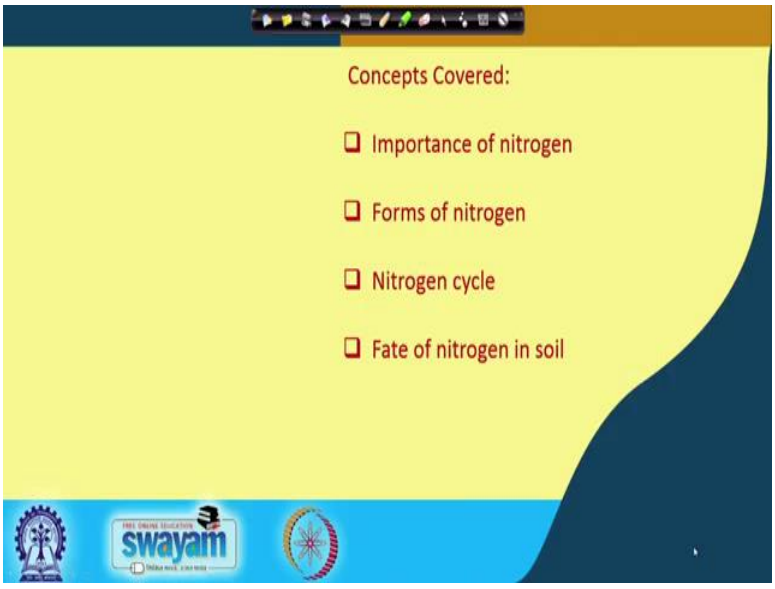

First of all we will see importance of nitrogen, then we will see different forms of nitrogen and then, we will see the nitrogen cycle and different processes which are involved in a nitrogen cycle and finally, we will see the fate of nitrogen in soil.

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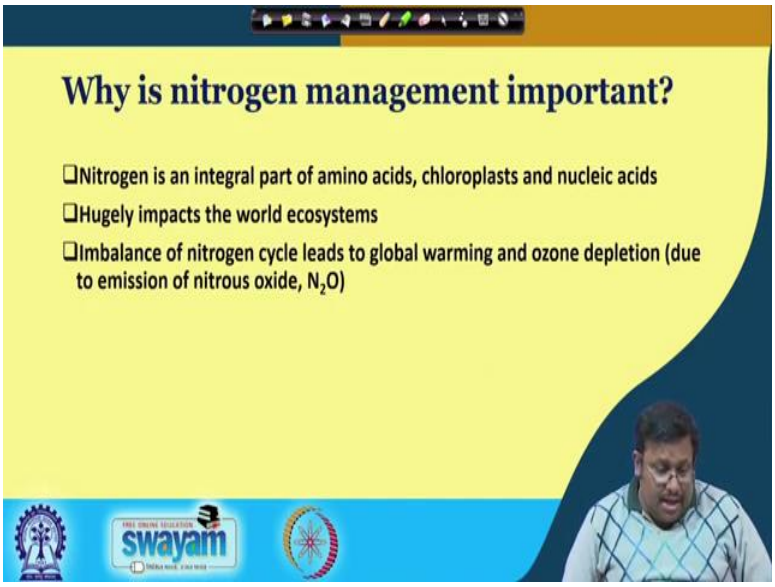

So, let us start with the nitrogen importance. So, why the nitrogen management is important? Now, you know that the nitrogen is an integral part of amino acids and chloroplasts and nucleic acids. So, it is an integral part of you know of you know it is of protein which is building block of any biological organisms and it hugely impacts the world ecosystems obviously.

So, imbalance of nitrogen cycle basically leads to the global warming and ozone depletion because, of the formation of the nitrous oxide and we will discuss why nitrous oxide forms basically nitrous oxide forms due to the process of denitrification. We will see that process later on. So, remember that nitrogen is very very important because, you know without nitrogen the you know the plant body cannot be constitute.

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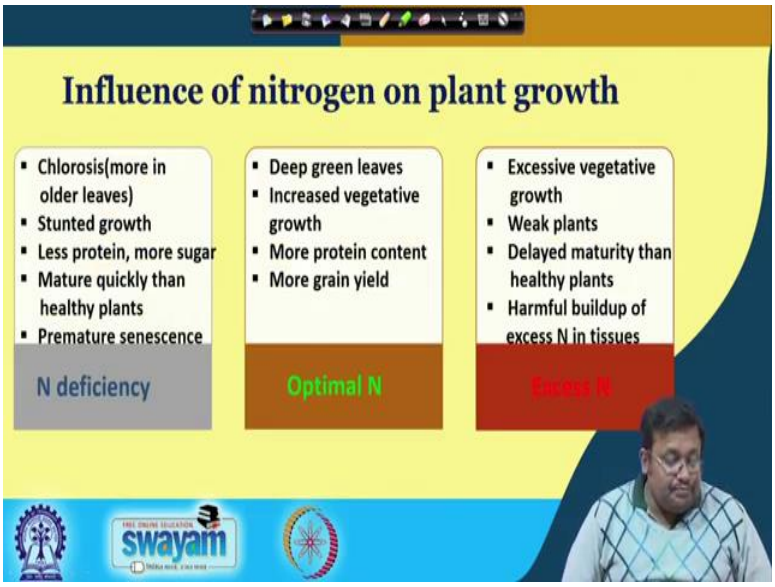

So, influence of nitrogen on plant growth you can you know see you know based on the abundance of nitrogen in the plant. We can divide their status as nitrogen deficiency, optimal nitrogen and excess of nitrogen. So, obviously in case of nitrogen deficiency you will see chlorosis condition that is in case of older lower leaves, they are turned you know pale, they are turned yellow in colour. So, we call it chlorosis and we have seen the you know we have seen the chlorosis in our previous lecture and also it will show the stunted growth and it will give the less protein and more sugar, mature quickly than healthy plants.

And finally, it will give the premature senescence which is the ageing of the plant and so; these are the deficiency symptoms of the nitrogen for the plant body. However in case of optimal nitrogen, you will see that they are deep green leaves and increased vegetative growth and you know they are more protein content and finally, you will see that more grain yield. So, this basically indicates the optimal nitrogen content and excess of nitrogen that is also harmful. So, when the deficiency is also harmful and excess of any particular element is harmful.

So, when there is an excess of nitrogen, you will see some deleted effects on the plant health that is excessive vegetative growth and you will see weak plants and subsequent

lodging of the plants, delayed maturity, then healthier plants and harmful build up of excess nitrogen in tissues. So, these are the different effects based on the nitrogen content in the plant.

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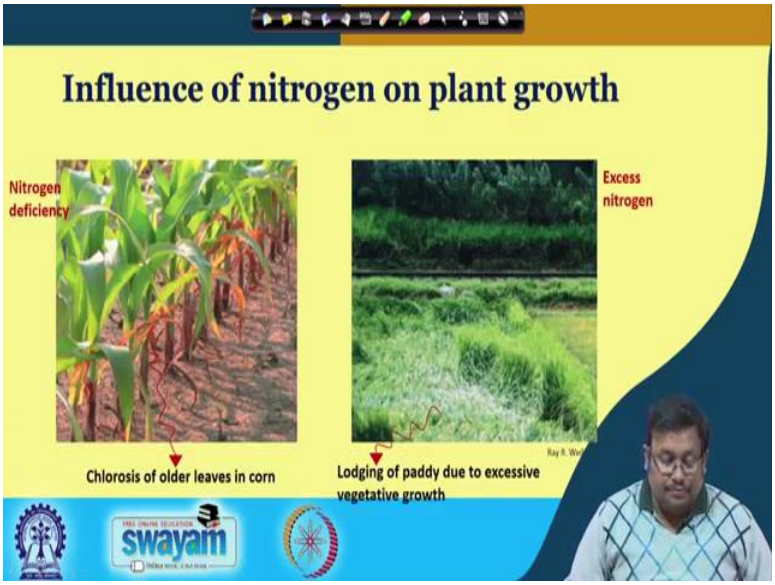

So, let us see some pictures of let us see some photos. So, you can see that chlorosis of older leaves in corn. So, obviously the nitrogen deficiency will be seen in the lower leaves and it will turn yellow. So, we call it chlorosis of leaves and you will also see the stunted growth and in case of excess nitrogen, obviously there will be excessive vegetative growth and weak plants.

As a result when there is you know when there is a wind blow or any you know automatically the plants will lodge and we can see here lodging of the paddy due to excessive vegetative growth. So, this is also harmful for the growth of the plant. So, we can see the two extent conditions when in one case there is nitrogen deficiency and in another case there is a excessive nitrogen.

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What are the different forms of nitrogen? Obviously, you can see there are two major forms of nitrogen plant can uptake; one is ammonium and another one is nitrate. So, these are inorganic forms. So, available forms are basically ammonium and nitrate and ammonium uptake lowers the rhizosphere pH. I already told you in my week 6 lectures that whenever the plant will uptake ammonium and they will release the they will release the protons to balance, these nutrient imbalance to balance these transfer of nutrients, transfer of ions and as a result there will be lowering of the pH because uptake of ammonium again will release the H plus and these H plus is required for soil acidity.

So, soil acidity will increase when there will be ammonium uptake with the rhizosphere region, however the similar the voice you know the opposite effect is found in case of nitrate. So, obviously when there is a nitrate removal or when there is a nitrate uptake, obviously you will see the opposite effect. So, there will be there will not be any reduction of pH. So, dissolved organic compounds also supplying you know nitrogen in organic forms and among these various forms uptake depends on their availability and the crop. We will see that later on.

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So, let us see what are the different organic nitrogen pool. So, if you see there is a total organic nitrogen, total organic nitrogen has two different other pools also. One is called the SON; another is called the DON. The SON basically denotes the Soluble Organic Nitrogen and DON basically denotes the Dissolved you know Organic Nitrogen.

So, the soluble organic nitrogen basically portion of organic nitrogen which can be easily extracted using salt solutions like KCl or water and the DON is basically the portion of soluble organic nitrogen present in salt solution and drainage waters and reasons they are basically these DON is the reason for inherent fertility of some forests and basically they are easily leached. So, there is a potential state for environmental you know environmental contamination specially in downstream areas. So, you can see these two nitrogen organic pools, however again remember for plants the essential forms are ammonium and nitrate.

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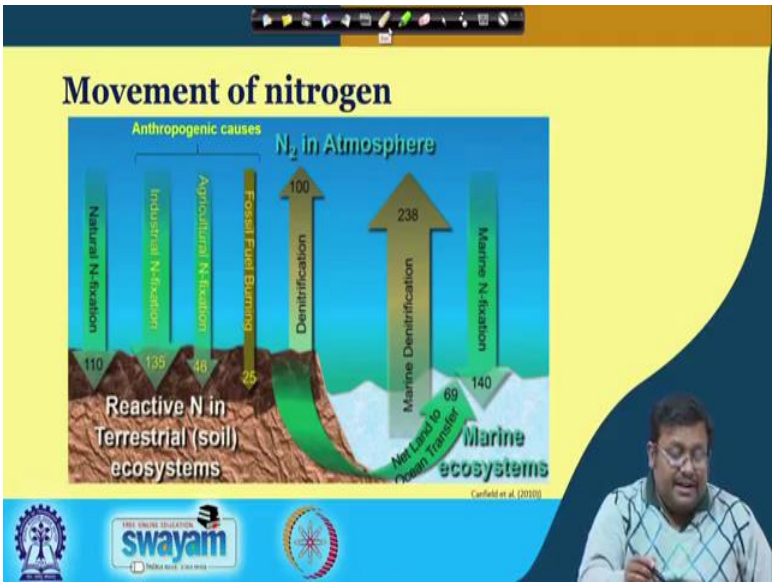

So, what are the different you know you know in if you if you consider the terrestrial ecosystem and marine ecosystem, what are the different pathways of nitrogen transfer? You can see some anthropogenic courses are you know anthropogenic causes are given here. And anthropogenic causes for nitrogen fixation, you know nitrogen addition are industrial nitrogen fixation obviously and then agriculture nitrogen fixation and then fossil fuel burning.

So, all these are anthropogenic causes and also there is a natural nitrogen fixation. So, all these are inputs of nitrogen, however nitrogen in the atmosphere basically goes in the form when the denitrification takes place. So, denitrification is basically conversion of nitrate into gaseous nitrogen by different micro organism specifically in the anaerobic condition. We will discuss that in detail. So, denitrification basically converts the inorganic form of nitrogen ultimately to the gaseous nitrogen. So, these gaseous nitrogen ultimately release into the atmosphere. So, this is called the denitrification process and also, there is a marine denitrification and marine nitrogen fixation.

So, all these process are occurred you know all these process are occurred in terrestrial ecosystem basically soil ecosystem as well as marine ecosystem. So, this is very important to learn these dynamics while you know study the soil nitrogen cycle.

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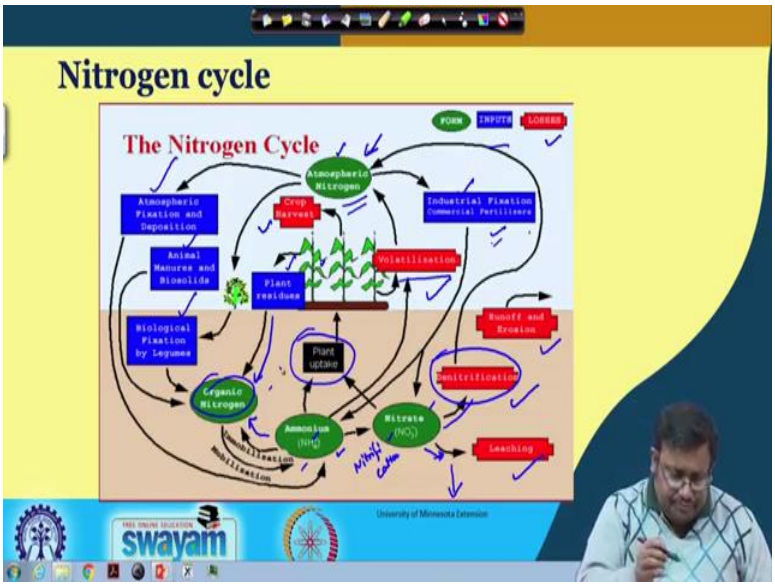

So, this is the soil nitrogen cycle or nitrogen cycle in nut shell. So, please understand in very very carefully and you can see here first let us start with the plant. So, when the plant dies, their bodies are plant residues will basically decompose and they will go towards this organic nitrogen. As a result of decomposition, all the organic nitrogen which is present in the plant body will be released and these organic nitrogen will ultimately immobilization in the form of you know they will basically mineralise to form mineral forms of nitrogen. So, the first mineral form of nitrogen from organic nitrogen is ammonium and this ammonium will further you know you know in the process of nitrification in the process of nitrification, it will convert into nitrate and the opposite process of conversion of this mineral ammonium to the organic forms of nitrogen is called immobilization.

So, again first of all the when the plant dies, their plant residues. As a result of decomposition, organic nitrogen will generate and these organic form of nitrogen will further you know convert into the ammonium form. We call it mineralisation and this conversion of organic form into inorganic form is called mineralisation and this ammonium form will further convert into nitrate form in the process of nitrification and the opposite of conversion of ammonium the opposite process that is conversion of ammonium to organic form is called the immobilization.

Now, this nitrate nitrogen is highly mobile with water, so highly soluble. So, when it is highly soluble, it is also there is also chance of losing this nitrate by the leaching process and leaching is basically downward movement of you know water dissolved dissolving in different salts. So, this nitrate will dissolve easily in the in the in the water and it will leach down and further in the anaerobic condition. These nitrate will convert into atmospheric nitrogen. You can see here it is converting into the atmospheric nitrogen here to the process of denitrification and this denitrification occurs in anaerobic condition. Also these nitrate can you know removed from one place to another place in the through the process of run-off and erosion.

Now, these atmospheric nitrogen, these atmospheric nitrogen you know we can use that for industrial fixation in the case of different producing, different commercial fertilizers. So, when we produce some commercial fertilizer, we add. You know one of the major ingredient is nitrogen gas and this nitrogen gas is basically coming from atmosphere nitrogen. So, it is one is it is a way of industrial nitrogen fixation and ultimately these commercial fertilizer who will ultimately goes to these ammonium pool because it will react with the soil and ultimately goes to the ammonium pool.

Remember that from this ammonium pool and nitrate pool, these two will go to for plant uptake because plant only can take this to forms of nitrogen. Another important aspects is in the you know sometime this ammonium also release into the atmosphere to the volatilization process. So, this ammonium ion will convert to gaseous ammonia as this gaseous ammonia will go to the atmosphere and finally, it will reach the atmospheric nitrogen. So, this is called the Volatilization process or Ammonium Volatilization process. When the crop is getting removed and after the harvesting, this is another way of loss.

So, basically and the so I have covered all of them. So, you know some of them are here so, atmospheric nitrogen so atmospheric fixation and deposition. Obviously, when the atmospheric nitrogen is mixed with some water vapour and produces some you know some nitric acid and ultimately deposits into the soil to form different in the form of acid rain that is also atmospheric fixation and deposition.

Animal manures and bio solids also are organic forms of nitrogen. They will come after decomposition, they will come to this organic nitrogen form and then further it will continue this way and the biological nitrogen fixation by legumes is another way through which they can fix this legumes crop basically fix atmospheric nitrogen to different organic forms. So, again this is a nitrogen cycle. The blue are the basically the inputs. So, you can see the industrial fixation by producing by application fertilizer plants, plant residues, biological nitrogen fixation, animal manure and these atmospheric fixation and deposition are the inputs.

Different types of lightening effects also helps in this atmospheric fixation and deposition and these red blocks are basically different types of losses like leaching is a permanently leaching is a kind of loss, denitrification is a loss to the atmosphere, run off erosion is an loss. Obviously, volatilization is further a loss and crop harvest. So, all these are loss and forms are given in this green cell you know oval shape oval shape form.

So, you can see atmospheric nitrogen is one of the form and then, ammonium nitrate and organic nitrogen are the other forms. So, basically these are the snap shots of nitrogen cycle. Nitrogen cycle is more complex, however you can basic idea about the different processes which are going on in the soil nitrogen by just looking at this cycle diagram.

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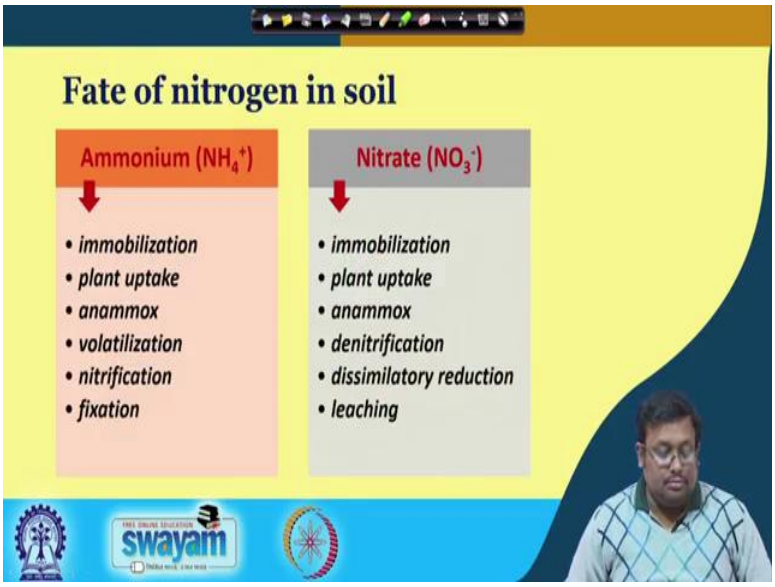

So, so what are the different fate of nitrogen in the soil? Obviously, these ammonium and you know and nitrate they are they are converted into different forms based these processes. So, immobilization we have already told that immobilization is a conversion of ammonium nitrogen to organic form of nitrogen. So, inorganic to organic form of nitrogen and ammonium also get you know up taken by rice plant. So, it is a you know plant uptake is a fate. Obviously, anammox we will discuss that later on.

Volatilization is a conversion ammonium to ammonia gas and then, nitrification is obviously conversion of ammonium to nitrate and fixation several clay minerals also fix these ammonium ions and that we will discuss later on. In case of nitrate, obviously, this nitrate is immobilization because the conversion of nitrate form to organic form is immobilization plant uptake. Plant you know loves this form and they uptake this nitrate. Anammox process that we discuss later on.

Denitrification is a conversion of nitrate to atmospheric nitrogen or gaseous nitrogen in the anaerobic condition. Dissimilatory condition is another way of nitrate conversion and finally, leaching which is the removal of nitrate through water downwards the soil profile. So, these are basically given the snapshot of different pages of these two you know available forms of nitrogen and we will discuss them one by one.

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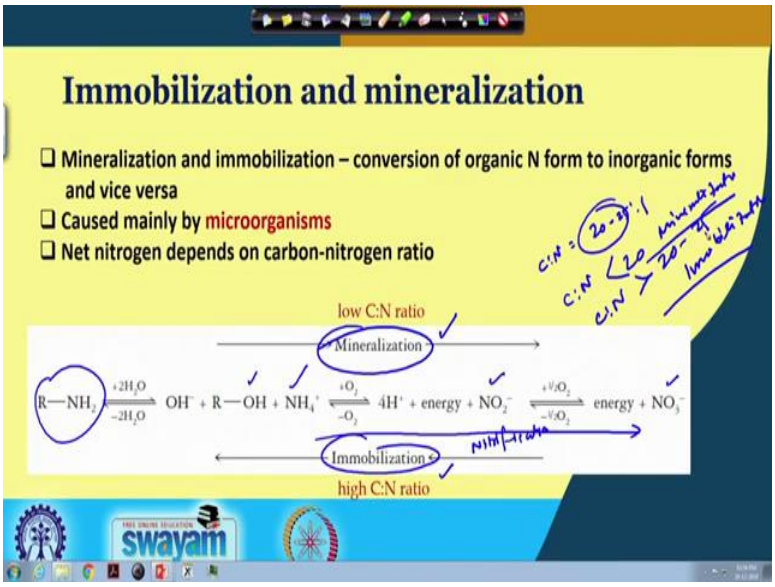

So, let us start with the immobilization and mineralization. The mineralisation and immobilization basically conversion of organic nitrogen form to inorganic forms and vice versa. So, when the organic form of nitrogen converted to the inorganic form of nitrogen, then we call it the mineralisation and the opposite process is called the immobilization and these two processes are basically radiated by various microorganisms which are present in the soil and specially the bacteria and net nitrogen depends on carbon nitrogen ratio.

So, let us see the conversion of different mineral of different forms of nitrogen. So, R NH 2 basically denotes the organic forms of nitrogen or amino acids. So, you can see this RNH 2 further getting you know breaking down into ammonium and then some alcohol and these you know ammonium further oxidized to produce nitrite and this nitrite further oxidized to produce nitrate.

Remember this, the conversion of ammonium to nitrite and the nitrite to nitrate is known as the nitrification process. So, this is the nitrification process. We call it as nitrification process and the conversion of organic form of nitrogen to inorganic forms of nitrogen is called the mineralisation process and immobilization process is the conversion of inorganic forms to organic forms.

Remember that the CN ratio that is carbon to nitrogen ratio is very very important for maintaining these or determining which will dominate which process will dominate, whether the mineralisation will dominate whether the immobilization will dominate. Remember that generally the optimum CN ratio is considered 20 to 25 is to 1. So, where the CN ratio goes below 20, then mineralization is I am sorry when the CN ratio goes below 20 mineralisation is pre-dominant and when the CN ratio is where beyond 20 to 25, then we call it when we will see that immobilization will dominate. So, why they dominate we will discuss later on.

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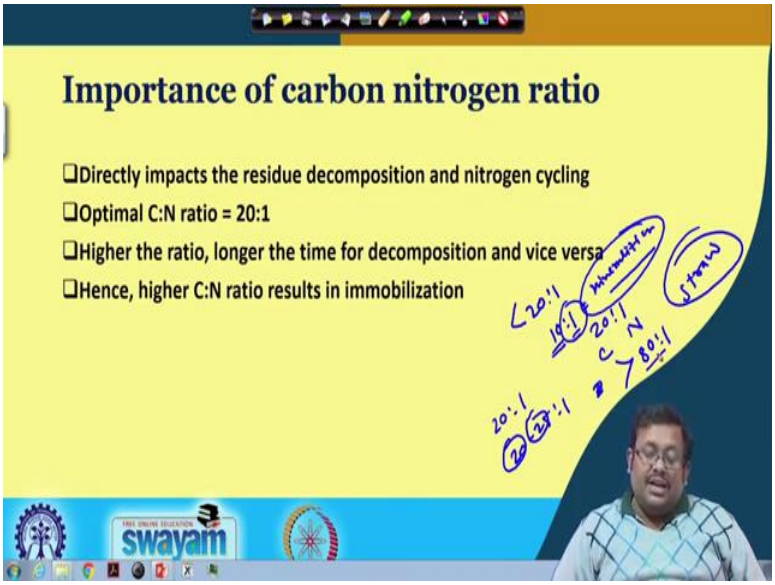

So, importance of carbon nitrogen ratio, now let us see what see what is the direct impact. Now, this CN ratio has direct impact on residue decomposition and nitrogen cycling. So, optimum CN ratio for maintaining the biological activity of the microorganism is generally 20 is to 1 because all these conversion that is mineralisation or immobilization or nitrification depends on microbial or microorganism activity.

Now, basically the optimum nitrogen or CN ratio for maintaining their activity is 20 to 25 is to 1. Sometime you will find it 20, and in some books you will get it 25. So, either is fine. So, remember that these ratio if there is a ratio 20 is to 1, that means the 20 units

of carbon per units of nitrogen. So, suppose there is a there is an element, there is a residue plant residue which has CN ratio less than 20 is to 1, suppose 10 is to 1.

So, that means there will be mineralization. Why there will be mineralization? Because all the microorganisms will eat away these carbon first because carbon is present in lower quantity as compared to nitrogen and then, they will release the unused or excess nitrogen to get decomposed further. So, as a result there will be mineralisation and when these ratio below C below carbon nitrogen ratio is greater than for example 80 is to 1 which we find in case of straw rice straw for example.

So, when we add this rice straw which have which is having higher CN ratio, then microorganism you know will immobilize the nitrogen in their body. So, there will be a conversion of ammonia, conversion of inorganic forms to organic forms. So, again this optimum CN ratio is 20 to 25 is to 1. Higher the ratio, longer the time for decomposition and vice versa and hence the higher CN ratio results in immobilization. So, if you want to enhance the rate of decomposition, we must add substance which is having lower CN ratio than 20 is to 1, ok.

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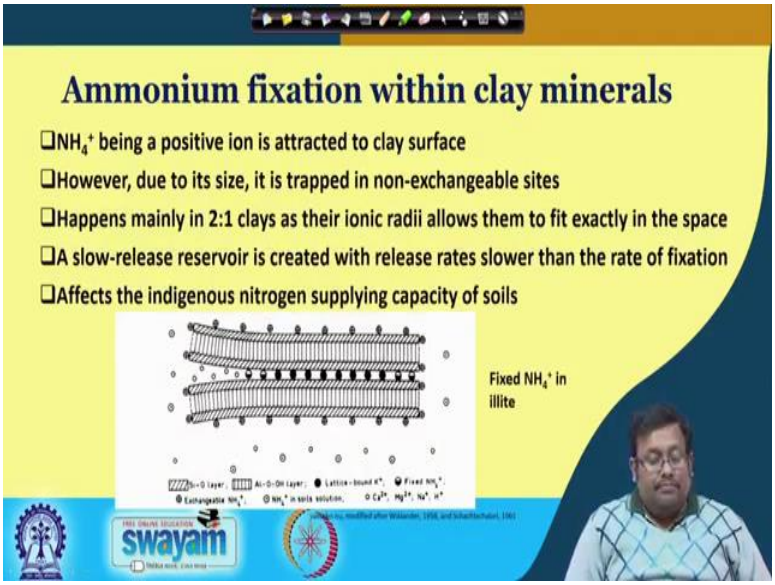

So, ammonium fixation within the clay minerals you know that ammonium being a positive ion also attracted to the clay surface because it generates the negative ions, negative charge in the clay surface, however due to its size it is trapped on the non-exchangeable sites and you can see here the silica layer is denoted by these and also, this is aluminium hydroxyl layer that is silica tetrahedral layer aluminium octahedral layer. So, these two silica tetrahedral layer and this is the one aluminium octahedral layer and these fixed ammonium in illite.

So, due to the small, due to the size it trapped in non-exchangeable sites and it happens mainly in the 2 is to 1 type of clay as their ionic radii allows them to feet exactly space and a slowly reserver is basically created with release rates slower than the rate of fixation and it basically effects the indigenous nitrogen supplying the capacity of the soil. So, you can see that this a fixed ammonium is basically at the intelliar space because the inter layer space is quite small.

It is if you remember illite the inter layer space is dominated by the potassium and it is basically collapsed. So, that is why illite is called the non-expending two to one mineral and only the ammonium can feet in that small space because ammonium has the similar ionic radii as that of potassium. So, you can see the ammonium can get fixed in the inter layer space also.

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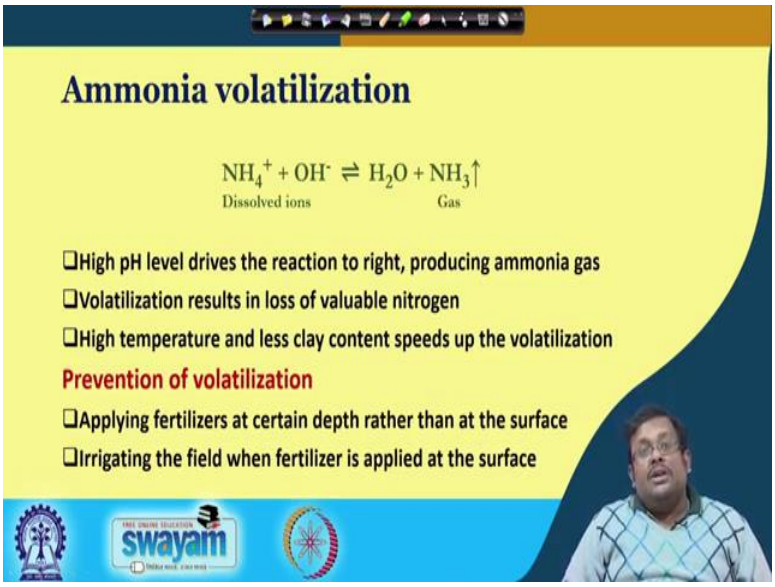

So, what is ammonia volatilization? Well when ammonia when there is a high level of pH, then the pH the high pH drives this reaction. For example, you can see here ammonium ion is reacting with hydroxyl and to produce the water and this ammonia which is escaping to the atmosphere. So, when there is a high pH in the soil, these drives this reaction to the right and ultimately it produces the ammonia which is further released to the atmosphere. So, this is called Ammonia volatilization and volatilization results in losses of valuable nitrogen.

So, this is one of loss of nitrogen and high temperature and less clay content also speed up the volatilization loss of nitrogen. So, how we can prevent volatilization loss of nitrogen? We can apply fertilizer at certain depth rather than at the surface, so that it cannot direct came come into contact with these hydroxyls and also irrigating the field when fertilizer is applied to the surface. So, these are some ways through which we can prevent the volatilization ammonia volatilization process.

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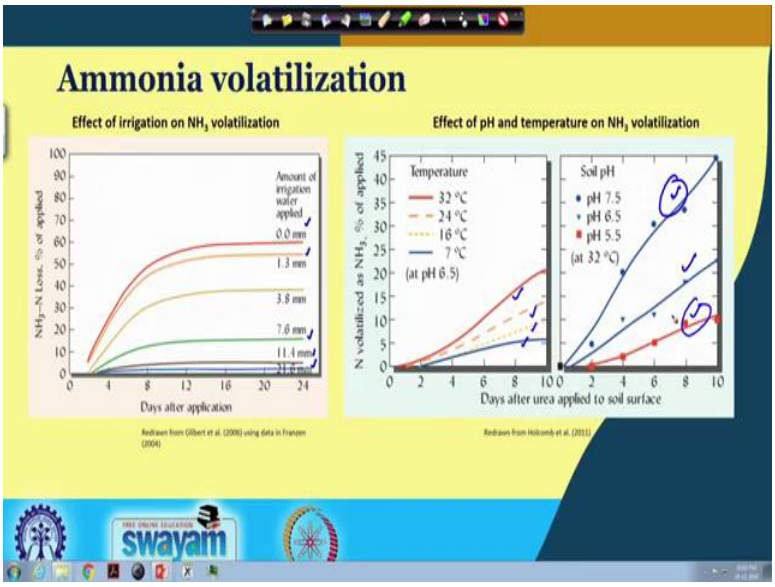

And the this graph basically shows the relation between the ammonia you know volatilization loss of ammonia and days after application and you can see as the and also basically shows the affect of irrigation on ammonia volatilization. So, you can see when you give more and more irrigation, obviously the loss of ammonia will be less. As you can see here the lowest ammonia released in case of this solid blue line because we are adding highest amount of irrigation water that is 21.6 millimetre of irrigation water. So, it basically shows the effect of irrigation on reducing the ammonia volatilization. So, it basically justify the solution which we discussed in our last line and also we can see here the effect of pH and temperature on ammonia volatilization.

So, basically you see that when with the x axis we are putting days after urea applied to soil surface which is a nitrogenous fertiliser and nitrogen volatilised as ammonia in the y axis, you can see as the temperature increases from 7 to 16 to 24 to 32, obviously the nitrogen volatilization loss increases and here you can see also with the with the decrease in pH here it is 7.5, then 6.5, then 5.5. So, obviously this higher pH condition that is alkaline condition basically favours the nitrogen volatilisation or ammonia volatilisation, however the acidic condition lowers the ammonia volatilisation.

So, guys we have covered some basic process of nitrogen transformation and we have discussed about the nitrogen cycle and important process. And in the next lecture, we will try to finish this and we will try to cover all the other important nitrogen transformation processes, nitrification and then denitrification, anammox and so on so forth.

And thank you and let us meet in our next lecture of week 7.