Soil Fertility and Fertilizers

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Lecture 03

Importance of Soil Nutrient Management and Basics Soil-Plant Relationship (Contd.)

Welcome friends to this third lecture of week 1 of NPTEL online certification course of Soil Fertility and Fertilizer. And in this week, we are talking about importance of Soil Nutrient Management and Basic Soil-Plant Relationship. So, in our previous two lectures, we have discussed about what is the importance of soil health, what are the indicators of the soil health, then we have discussed about what are the different types of laws, which are governing the plant nutrition for example, Liebig's law of minimum we have discussed.

We have also discussed law of diminishing return and also we have discussed the law of maximum apart from that, we have also discussed you know, why we call some nutrients as essential nutrients, what are the essentiality criteria of some nutrients, what is the classification of those nutrients based on their essentiality as well as the amount required, we have also seen what are the major forms, which are available plant available forms of different macro and micronutrients.

So, we have all discussed this thing in our previous lecture, we have also discussed the hidden hunger we have discussed the different types of deficiency symptoms a plant can produce due to the absence of a particular nutrient or we have also seen some toxicity symptoms also.

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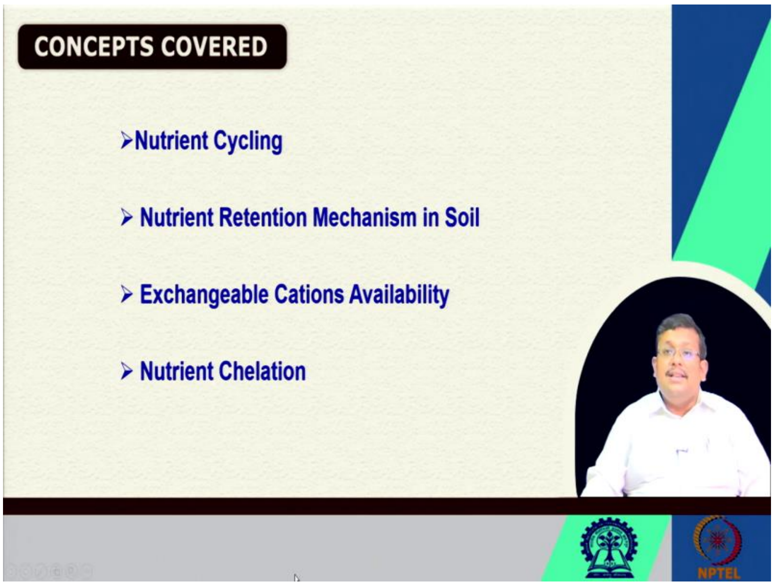

Now, in this third lecture, we are going to discuss these following topics we are going to first discuss the Nutrient Cycling and then we are going to discuss Nutrient Retention Mechanism in Soil and also, we are going to discuss Exchangeable Cations Availability and Nutrient Chelation. So, these are the four major concepts which we are going to discuss in this lecture number 3 of week 1.

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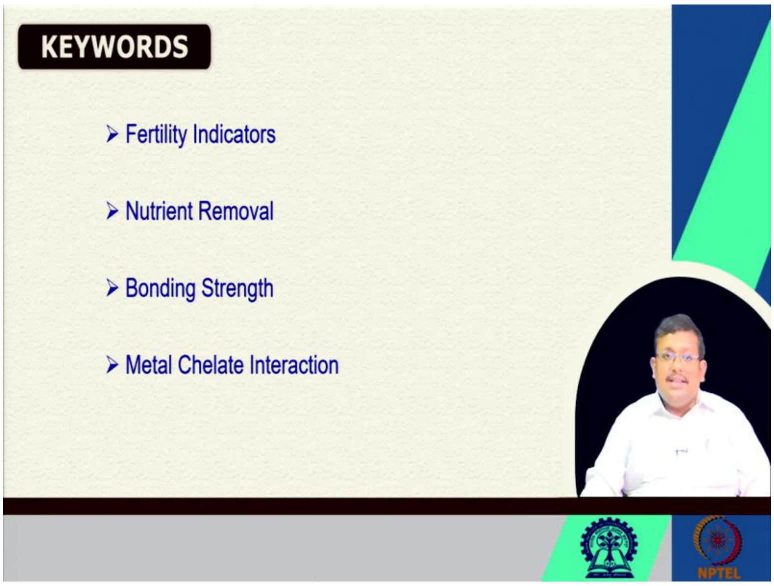

And these are the key words for this lecture Fertility Indicators, Nutrient Removal, Bonding Strength and Metal Chelate Interactions.

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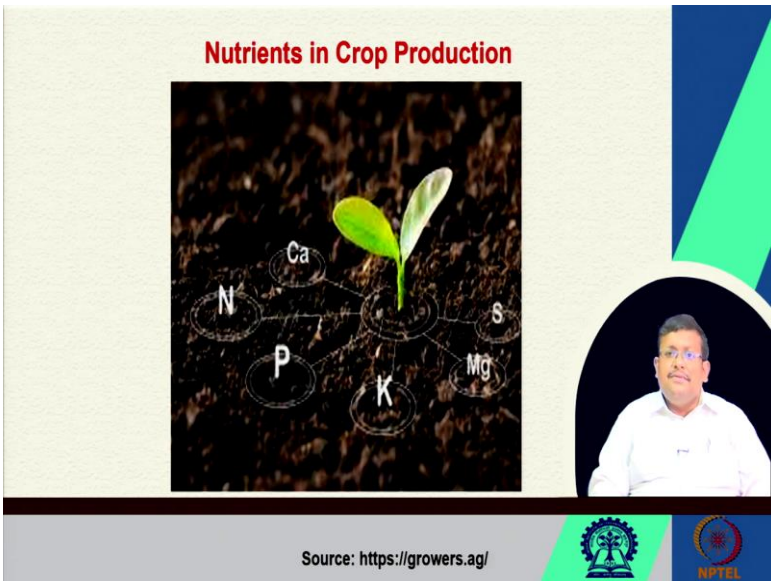

So, let us start, so, you know that nutrients are very much… useful for crop production and these are the major food for plant and most of the nutrients plant are getting from the soil and raised 3 that is carbon, hydrogen and oxygen they are getting from air and water. So, these are known as CHO are known as the structural elements apart from that the essential elements both macronutrients and micronutrients they are again they are getting it from the soil itself.

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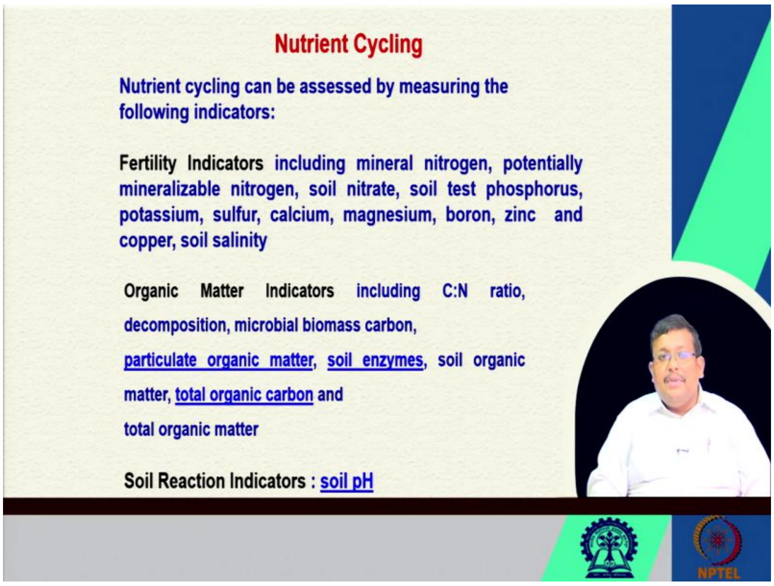

Now, what is Nutrient Cycling? Now, Nutrient Cycling basically is the dynamic interaction between different phases of soil to modify or transfer the plant essential nutrients from one form to another form. So, this is called nutrient cycling, nutrient cycling basically gives us the indication of how a nutrient is getting circulated among this soil environment. And so, this nutrient cycling can be assessed by measuring the following indicators.

So, first one is the Fertility Indicators. So, this fertility indicators includes mineral nitrogen as well as potentially mineralizable nitrogen, then soil nitrate, soil test phosphorus, then potassium then sulfur, then calcium then magnesium then boron, zinc and copper apart from that also soil salinity. So, it does not matter whether a soil is having high amount of these essential nutrients, if the soil is aligned, soil will become physiologically dry that means, in this condition in a saline soil condition plant cannot extract these nutrients from the soil.

Second category is, Organic Matter Indicators for example, CN ratio decomposition, microbial biomass carbon particulate organic matter soil enzymes, soil organic matter, total organic carbon and total organic matter all these are different organic matter indicators and organic matter you know it plays a major role in nutrient cycling in the soil.

Apart from that soil reaction indicators said they are like soil pH. So, soil pH is known as the one of the important soil property which governs the availability of different nutrients to the plants. So, soil pH is another important of nutrient cycling.

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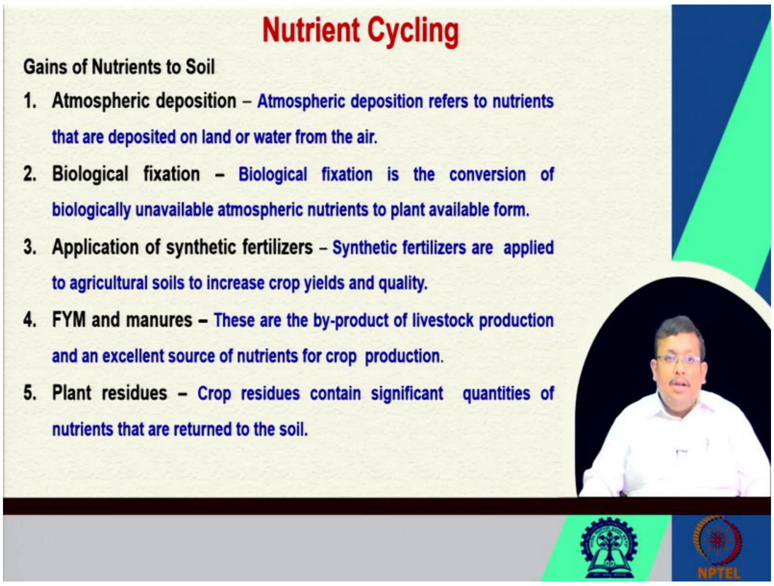

Now, what are the ways through which soil can gains nutrients, what are the different inputs of nutrients plant nutrients in soil. So, you can see here I have given five different inputs first of all atmospheric deposition, which is basically which refers to the nutrient that are deposited on land and water from the air.

So, due to rainfall, you know and due to different types of atmospheric events, when different nutrients are coming into the soil then it is called atmospheric deposition. Second one is biological fixation, biological fixation is the conversion of biologically unavailable atmospheric nutrient to plant available form, we are going to discuss this biological nitrogen fixation in our upcoming lectures in details. So, nitrogen is one of the major plant nutrient which gets biologically fixed by many different microorganisms and helps to increase the fertility status of the soil.

Third one is Application of synthetic fertilizers. So, synthetic fertilizer are applied to agricultural soils to increase the crop yields and quality. So, this is another major source of nutrients in the soil. Then, FYM and manures and other manures, these are the by-products of different livestock production as an excellent source of nutrients for crop production. So, these are also you know, different sources for a nutrients in the soil.

And finally, plant residues crop residues contain significant quantities of nutrients that are returned to the soil. So, these plant residues are also very much important for as a source of nutrients in the soil.

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So, we have seen the nutrient inputs let us discuss what are the ways through which nutrient gets removed from soil. Now, the first important thing is crop uptake and removal of nutrients from soil, now you know that nutrient used by plants are taken up in soluble inorganic free ions ionic forms from the soil solution and are removed from the soil when the harvested materials are you know are removed from the field. So, this is called crop uptake and as a result the nutrients are getting removed from the soil.

The second important way through which nutrients are removed from the soil is called the runoff, this is basically loss of dissolved nutrients in water moving across the soil surface. So, there are different you know reason for runoff and there are different types of cultural practices, which we can follow to reduce the nutrient loss through runoff.

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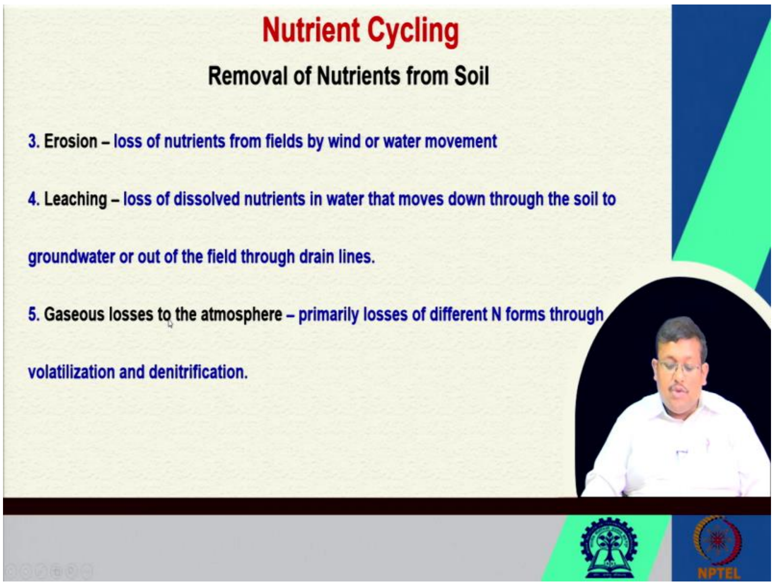

The third important you know pathway of nutrient loss from soil is Erosion that is a loss of nutrients from fields by wind or water movement. So, it could be wind erosion it could be water erosion. The fourth pathway is the leaching which is basically loss of dissolved nutrients in water that moves down to the soil to groundwater or out of the field through drain lines.

The fifth one is gaseous losses to the atmosphere, it primarily you know primarily nutrient losses through gaseous form can be seen in different nitrogen in the different forms of nitrogen through volatilisation and denitrification. We are going to discuss these two terms in details in our upcoming lectures. So, these gaseous losses to the atmosphere is another important pathway for nutrient removal from soil.

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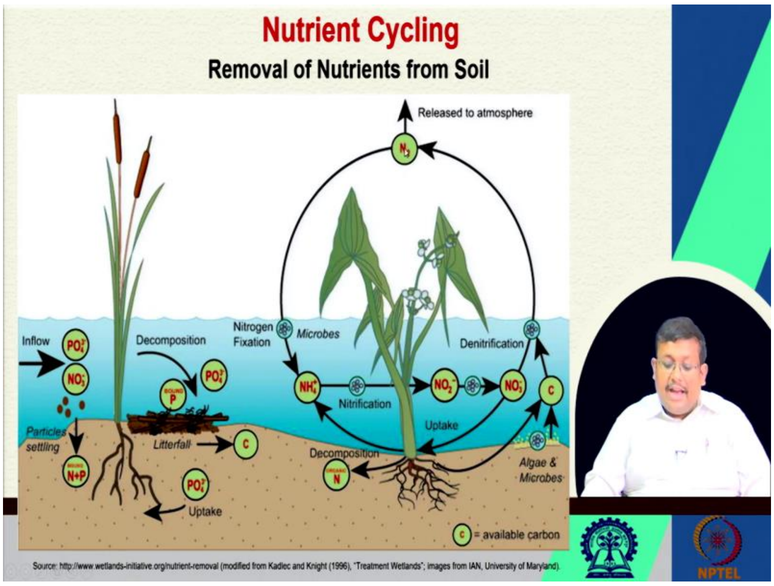

So, for example here you can see this is a wetland condition and of course, in this soil this is an anaerobic condition because there is a standing water when there is an anaerobic condition these nitrates or the oxidized form of nitrogen can cannot be present and as a result they are going they are reduced to at you know this nitrogen gaseous form and released to the atmosphere. So, this process is known as the denitrification process.

So, this is one of the way through which these nitrogen from is lost from the soil. So, this is denitrification process, we are going to discuss this denitrification process in more details in our upcoming lectures.

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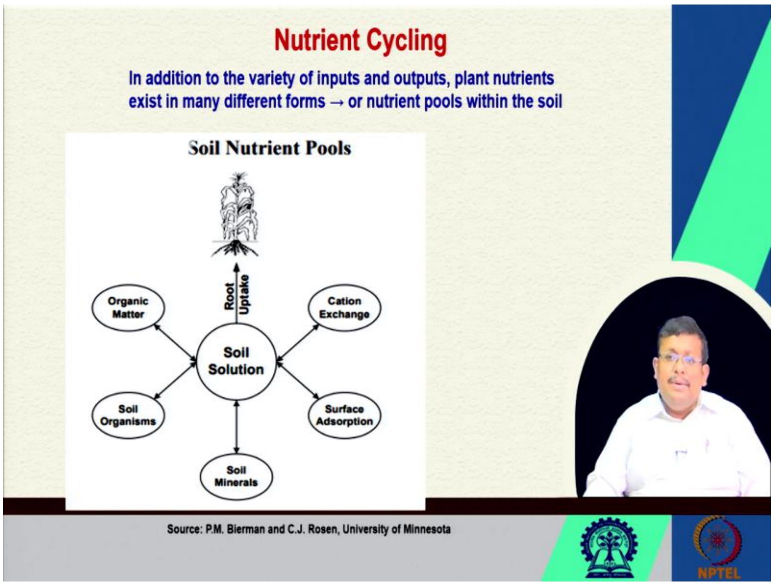

Now, in addition to the variety of inputs and outputs, plant nutrients exist in many different forms or nutrient pools in the soil. For example, nitrogen can remain in different pools phosphorus can remain in different pools in the soil and these phosphorus and you know potassium can remain in different pools in the soil like a you know soil solution potash, then exchangeable potassium, non-exchangeable potassium, structural potassium.

We are going to discuss this in details in our upcoming lectures, but remember that these nutrients or the available forms of the nutrients are there in the soil in different pools and individual pools basically, they contribute to contribute these nutrients to the to the soil solution from which the plants uptake these nutrient through their roots.

So, here you can see how you know different mechanisms are involved for contributing these ions to the soil solution like cation exchange, surface adsorption and from soil minerals from the soil organisms and organic matter. So, all these different types of you know, processes are contributing these nutrients in the soil solution from which plant root uptake these nutrients.

So, that shows that dynamic interaction between different pools and different processes, which are going on in the soil in different phases like mineral phase… then organic matter phase and you know soil solution phase, which are ultimately governing the uptake of the nutrients by the plant root.

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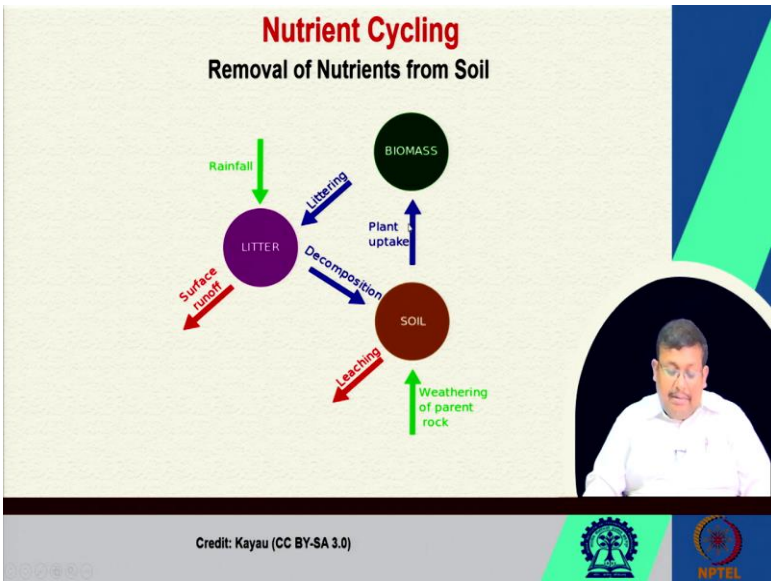

Now, here in this picture, we can see the different ways through which the nutrients are getting removed from the soil here you can see you know the soil from here, the plant uptake the nutrients and creates the biomass. Now, this biomass not only the plant, but also the animal residue also. So, when they decompose they lead you know to the littering process they create the letter and also there are two inputs like through rainfall, atmospheric deposition we have discussed and also through weathering of the parent rock.

So, weathering of the parent rock enriches the soil with different nutrients and also when there is a litter formation, rainfall can add also different nutrients in the litter. So, these are different processes through which these nutrients move from soil to biomass and later, ultimately you can see there are two pathways to removal for removal of nutrients, you can see here, this is surface runoff from this litter and also leaching loss from the soil.

So, this basically takes a snapshot of different gains and losses of nutrients from the soil, here we can see the soil is gaining the nutrients from the weathering of the parent rock litter is getting the nutrient from the rainfall and also this from the soil this biomass is generating these biomass consists of both plant as well as animals and they create the litter and after that, you know simultaneously there are surface runoff and also leaching to which nutrients are moved or removed from the soil.

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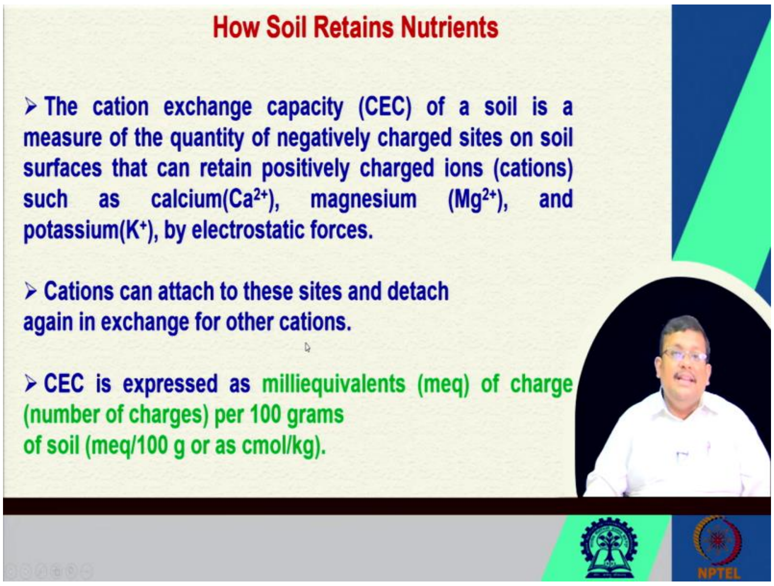

Now, how soil… Now, next question comes to our mind how soil retains nutrients? Now, the catenation capacity of a soil is majorly responsible for holding those nutrients to the soil surface. Now, what is catenation capacity? Catenation capacity of a soil is a measure of the quantity of the negatively charged sites on soil surfaces that can retain positively charged ions like cations such as calcium, magnesium and potassium by electrostatic forces.

So, it is basically the ability of the soil to attract this positive charge cations through electrostatic forces. Now, cation can attach to the sides and detach again in exchange for other cations. Generally, CEC expressed as milliequivalents of charge per 100 grams of soil. So, the unit is milli equivalent for 100 gram or sometimes we also express the CEC as centimole per kg.

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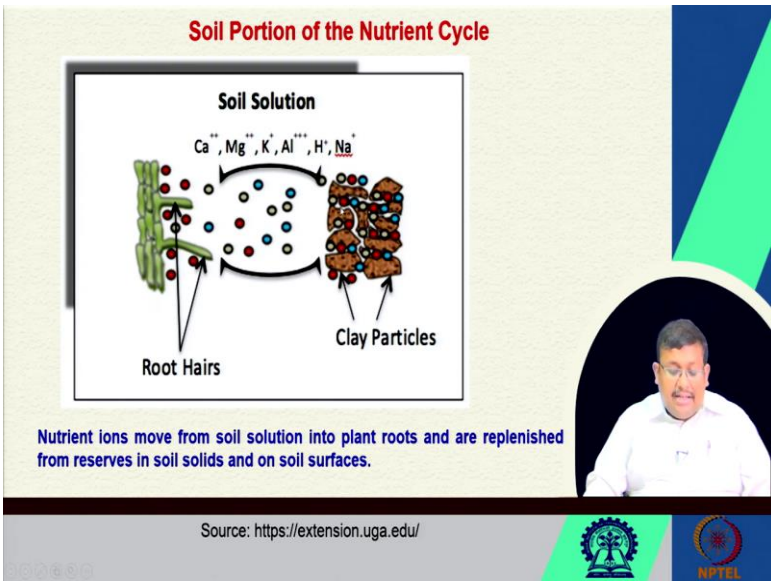

Now, if you see that, how these nutrients are moved from soil to root. So, here you can see these nutrients are which are attached to the clay particles they are getting exchange at these root surface and these root hairs are also absorbing these nutrients. So, here you can see these nutrient ions move from soil solution into the plant roots and replenished from reserve in soil solids and on soil surface.

So, what happens, these nutrients are going moving and migrating from the soil surface to the root surface where they are getting the absorbs and absorbed and the soil is basically, that is basically considered as a reserved of nutrients, the soil solids, so soil solids here is acting as a reserve of these nutrients, which generally replenish these nutrients into the soil solution once they are you know, they are uptake, uptake and by the plant root.

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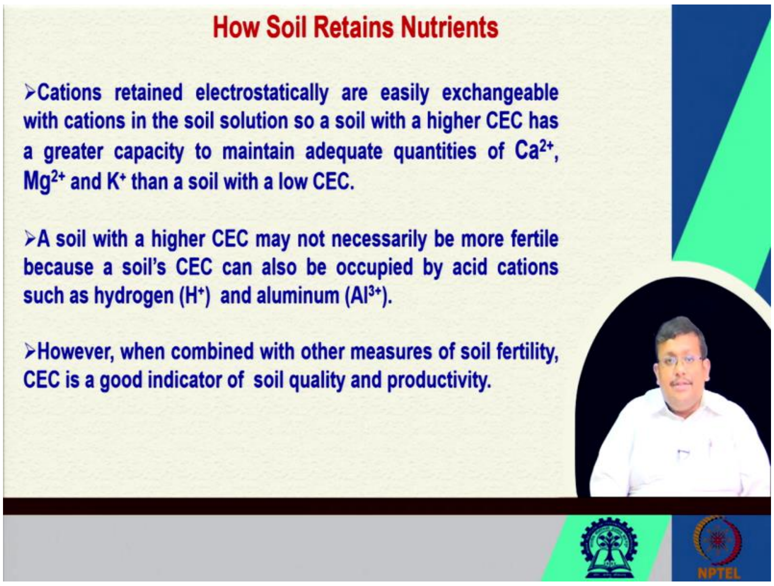

So, cations retain electrostatically are easily exchangeable with cations in the soil solution. So, as a soil with higher catenation capacity has a greater capacity to maintain adequate quantities of calcium magnesium and potassium and then a soil with the low catenation capacity.

So, a soil with higher catenation capacity may not necessarily be more fertile because a soils catenation capacity can also be occupied by acid catalysts such as hydrogen and aluminium, we have to be very very careful because hydrogen and aluminium these are also cations but these are these are not beneficial for the plant, rather they are toxic for the plant.

So, when we are calculating the catenation capacity, they are also involved in this calculation. However, they cannot be you know, if a soil is rich with hydrogen and aluminium we cannot consider that soil is a fertile because that will impact the crop negatively. However, when combined with other measures of soil fertility, CEC is a good indicator of soil quality and productivity. So, in general, we consider CEC as a good indicator of soil quality and productivity.

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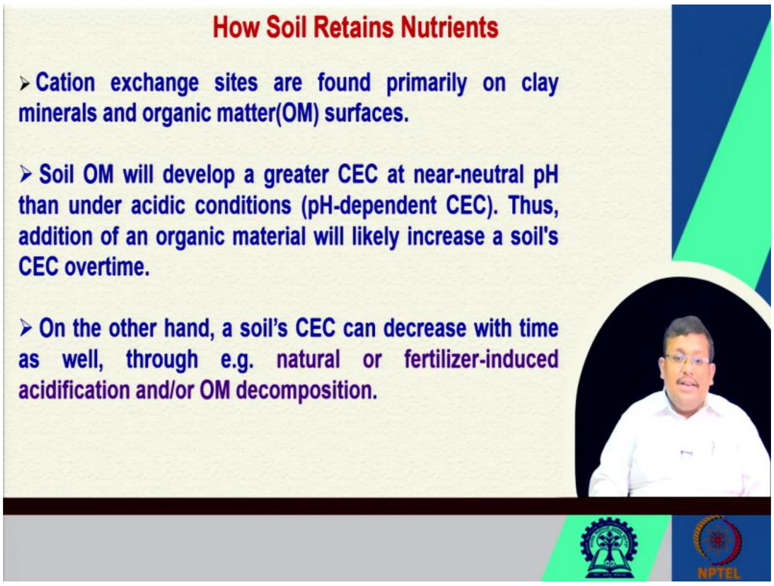

So, the cation exchange sites are found primarily on clay minerals and organic matter surfaces. So, you know that the soil generally develops this negative charge due to isomorphous substitution and at the same time, they also sometimes develop negative charge due to due to variable charge pH dependent charge and organic matter develops huge amount of negative charge. So, this negative charge are responsible for attracting this cation.

So, catenation capacity you know can be attributed to the negative charge develop in both the clay minerals as well as soil organic matter. Now, soil organic matter will develop a greater catenation capacity at near neutral pH then under acidic condition, so it is because it is a pH dependency CEC entirely the CEC which develops in soil organic matter is a pH dependent or variable charge-based CEC, thus addition of an organic material will likely to increase the soils CEC over time. So, that is why we generally recommend that you add organic matter in a non-infertile you know… non-fertile soil so, that the fertility of the soil can be enriched.

So basically, we are trying to increase the cation exchange capacity of the soil so, that the soil can retain these nutrients for plant growth. On the other hand, is soil CEC can decrease with time as well through different prices like natural or fertilizer induced acidification and also through organic matter decomposition. So, these are some of the ways through which the catenation capacity can also decrease in the soil.

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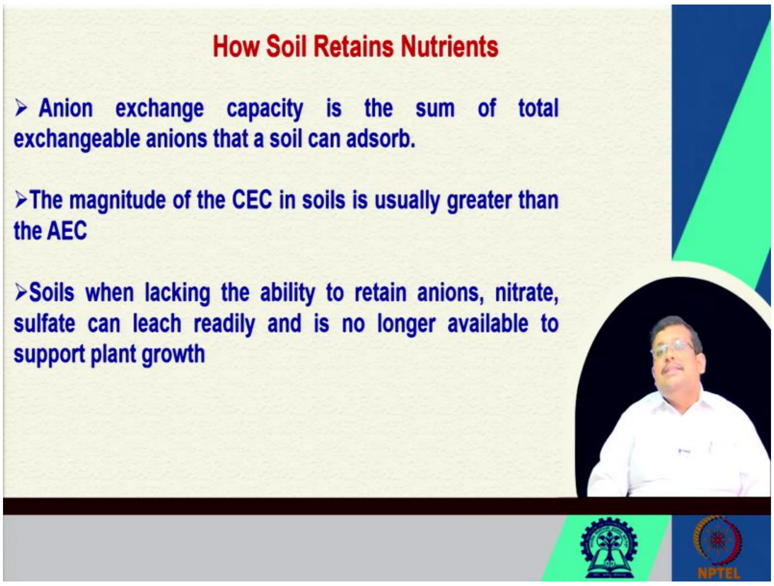

Now, enter the term is there that is called anion exchange capacity, anion exchange capacity is the sum of total exchangeable anion that a soil can adsorb, the magnitude of CEC in soil is usually greater than an anion capacity and soils will lacking the ability to retain anion nitrate sulphate can leach readily and in no longer and is no longer available to support the plant growth.

So, that is why these nitrate is very much susceptible to runoff loss because when they you know they are very soluble and when we apply the water in the field these nitrates get removed from the soil through the runoff process, because if there is you know low anion exchange capacity, these anions like nitrates and sulphates will not be attached to the to the clay surface and as a result, there will be repulsion and they will move freely through water from one field to another fleet and ultimately to the water body.

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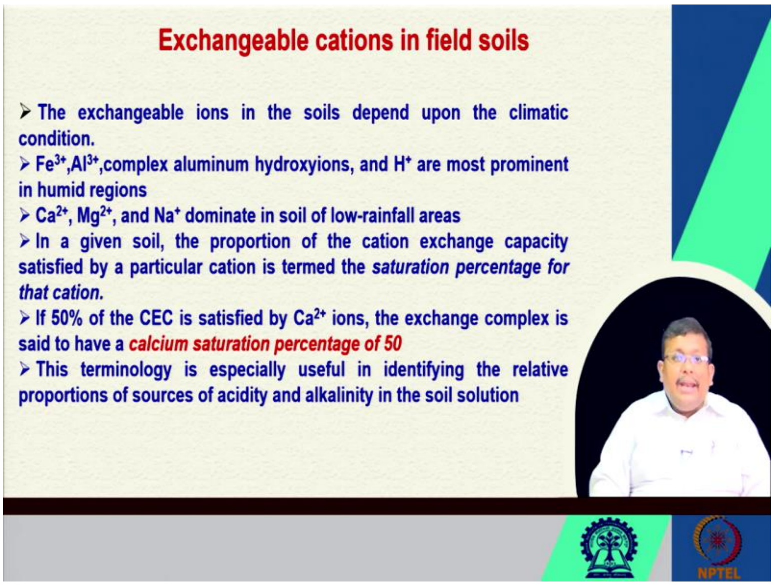

Now, what are the exchangeable cations in field soils? So, the exchangeable ions in the fields in the soils depend upon the climatic condition of course, so iron 3 plus Al 3 plus and complex aluminium hydroxyions and H plus are most prominent in humid regions, because in the humid regions, these ions generally forms and in the humid region there is generally we call it an acidic environment, where we can see the dominance of these iron aluminium ions, on contrary calcium, magnesium and sodium dominate in soil or low in soil of low rainfall areas.

So, when there is an arid or semi-arid condition, you will see that these soils are rich in calcium, magnesium and sodium, in a given soil the proportion of the cation exchange capacity satisfied by a particular cation is termed, the saturation percentage for that particular. So, if 50 percent of the catenation capacity is satisfied by calcium ions, the exchange complex is said to have a calcium saturation percentage of 50.

So, this… why this terminology is important? So, this terminology is especially useful in identifying the relative proportion of nutrition of sources of acidity and alkalinity in the soil solution. So, based on these saturation percentage, we can calculate we can have an idea about the relative dominance of a particular cation in the soil.

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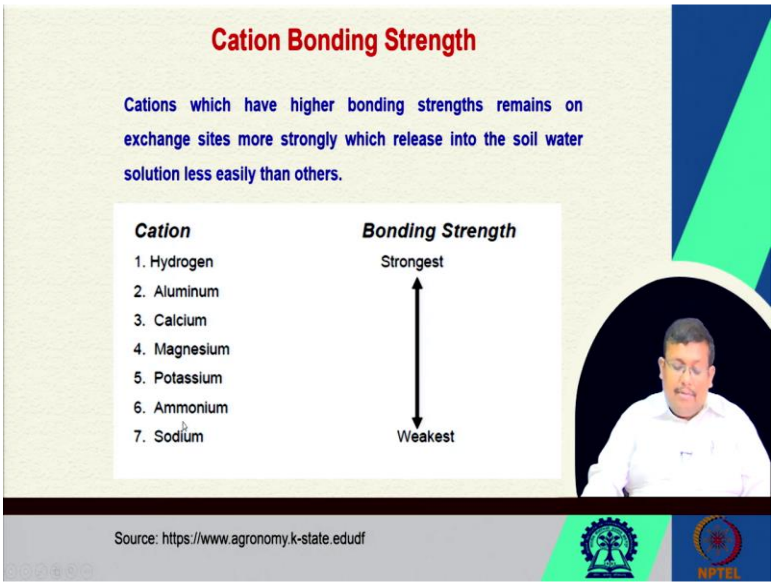

So, what are the different types of bonding strength of cation, so cations which have higher bonding strength remains on the action sites more strongly, which release into the soil water solution less easily than others. So, if you see here, different cations and they are like hydrogen, aluminium, calcium, magnesium, potassium, ammonium and sodium, among these, these are the strongly bound cations like hydrogen, aluminium.

And sodium, ammonium, potassium are weakly bound cations, among this sodium is the weakest showing the weakest bonding strength. However, in case of hydrogen, it shows the strongest bonding strength. So, this bond strength also plays an important role for nutrient cycling and nutrient movement inside soil.

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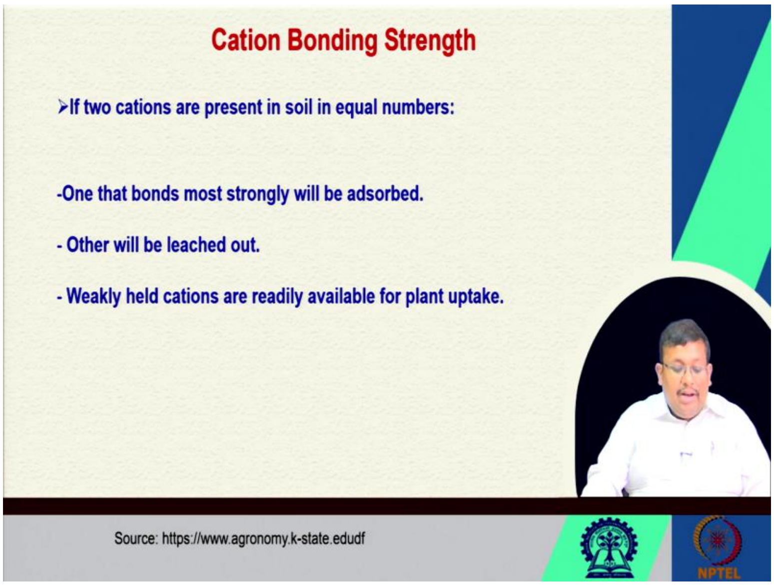

So, if two cations are present in soil in equal numbers, one that bonds most strongly will be adsorbed others will be leached out and weakly held cations are readily available generally for plant uptake. So, these are the implication of the bond strength of different catalysts in the soil.

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So, this is the let us discuss what is what are Chelates? So, chelates are you know, remember that some nutrients bond with some soluble organic compounds in soil to form ring complexes, and these ring complexes are known as chelates. So, these chelates come from the term chila or chela, which means claw. So basically, these organic compounds are basically forming a claw like complex where they are bound… where they are binding a particular nutrient and that is why the total you know the total structure is known as the chelate.

So, chelation increases the solubility of the nutrients preventing the formation of the insoluble precipitates and decreases the toxicity of some micro nutrients. So, this is how these you know these chelates are very much important for plant nutrition. Now, chelation increases the availability of the nutrients to the plants in soil chelated minerals are absorbed more rapidly by both plant roots and leaves and this faster nutrient transfer results in accelerated growth.

So, chelates, metal chelates are always helpful for plant growth, because they increase the solubility of the nutrients and they prevent the formation of the insoluble precipitates and also the decrease, the toxicities of the some micronutrients. So, all those chelated nutrients may not be immediately available, they are mobile and can quickly convert to plant available forms near the root surface.

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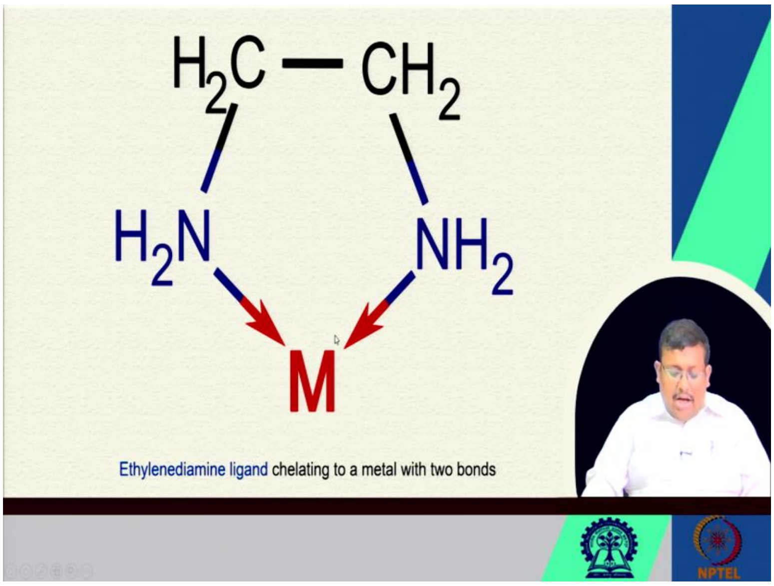

So, here you can see this is a chelate which is basically showing these Ethylenediamine ligand chelating to a metal with two bonds. So, here in the chelate the inorganic part or sorry the organic part is known as the ligand and here you can see how they are they are you know chelating to a metal with the two bonds. So, here this is the ethylenediamine ligand and ultimately, they are making a chelate with a with a metal ion.

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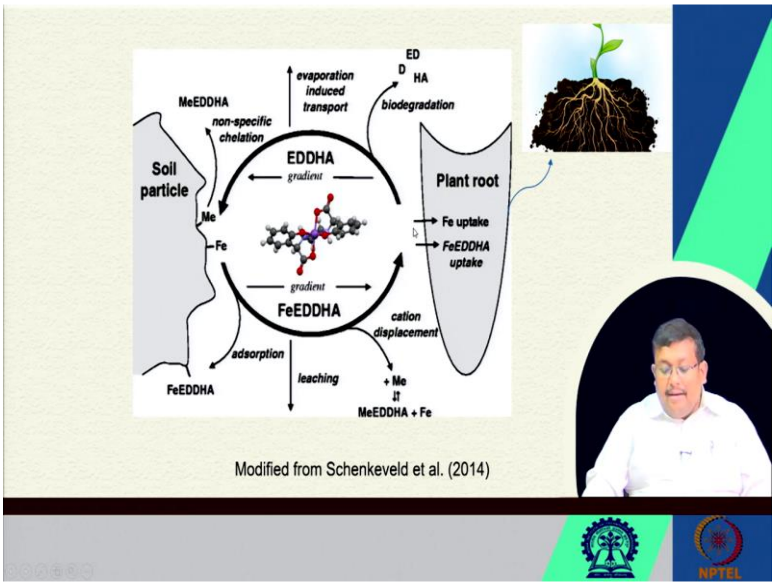

And this is how these chelates helps in plant nutrition you can see the soil particles you know in the soil particles these cations are adsorbed and when these EDDHA who is basically it is a chelating agent. So, this chelating agent basically forms a chelate that is FeEDDHA and ultimately reaches in the near the plant root and from where plant uptakes these iron for their growth.

So, these roots basically uptake these nutrients for their growth and then there is a further movement of the EDDHA from the plant root to the soil particle surface. So, here you can see a gradient of EDDHA from plant root to the soil particle surface however, the FeEDDHA which is a metal essential metal you know chelate their gradient is from the soil particles to the plant root.

So, this is how these metals are getting bounded by these different you know ligands from these chelating agents forming a chelate and ultimately goes to the plant root and releasing these particular essential elements for their uptake and then again gets back to the soil particles for further chelation

And in this selection process, there are different types of you know processes also can occur like adsorption then bleaching of these FeEDDHA and also there are some cation displacement can also occur. So, there are different types of processes which are going on in this chelate movement from soil to plant root.

So, we have discussed some of the important concepts today, we have discussed the indicators of nutrient cycling, we have discussed the cation exchange capacity, we have also discussed the chelates which are important source of plant nutrition. And I hope that you have learned something new. Let us wrap up this lecture here. And in the next lecture. We will start from here, and we will you know, we will discuss some more important issues related to the plant nutrition. Thank you.