Soil Science and Technology
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Lecture – 34
Soil P and K

Welcome friends, to this new lecture of Soil Science and Technology. And in this lecture we will be covering the two important plant nutrients; macro nutrients. These are soil phosphorus and potassium. And so the concepts which we will cover in this lecture are basically phosphorus and it is available forms and then fixation of phosphorus.

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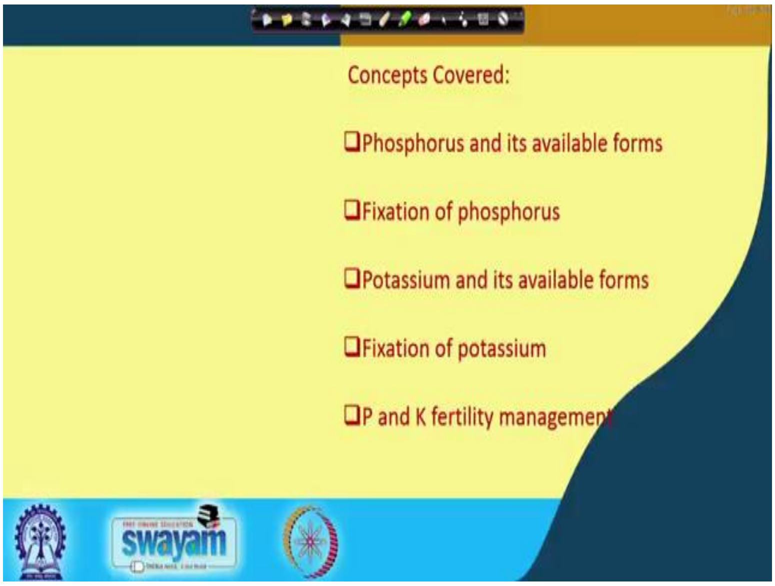

Then potassium and it is available forms, and then fixation of potassium, and then phosphorus and potassium fertility management.

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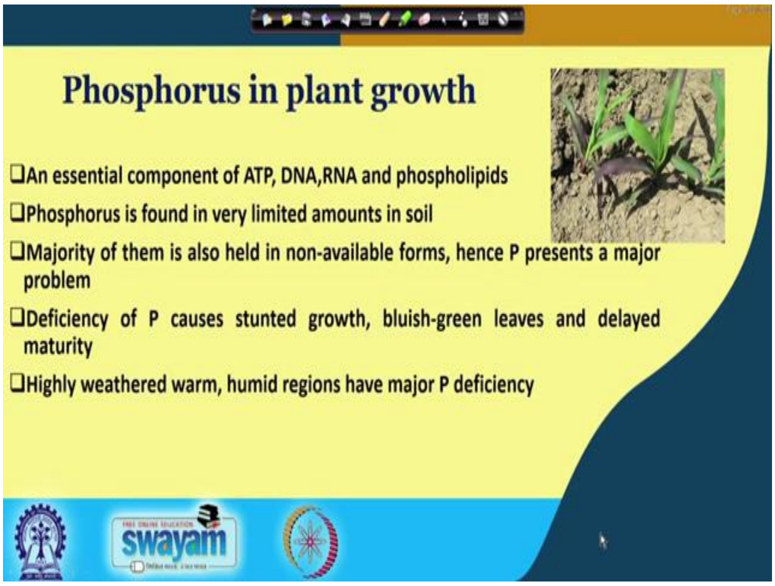

So, let us starts with the phosphorus you know that phosphorus is very important for plant growth it is. Because it is an essential component of ATP, DNA, RNA and phospholipids and phosphorus is found in very limited amount in soil. And there are several problems with phosphorus we will discuss them later on. But it is found in very limited quantity in soil and majority of them is also held in non available form.

So, phosphorus present a major problem. So, whatever amount of phosphorus is present majority of those fraction majority of that phosphorus is basically you know fixed by different chemicals which are present into the soil. So, most of the available phosphorus are in accessible to the plants.

So, deficiency phosphorus also very important and because of this fixation process and the deficiency of phosphorus causes stunted growth bluish green leaves and delayed maturity. As we can see in this picture it is showing the stunted growth and as well as the bluish green leaves. And you know where sometime reddish in colour and also sometime delayed in maturity.

So, this are the important deficiency symptoms of phosphorus. Now also highly weathered warm and humid regions have major phosphorus deficiency. Because you know we will see what are reasons behind; but just remember that in this region there is a high amount of different aluminium and iron bearing minerals. So, this aluminium and iron basically fix this phosphorus in this conditions so creating phosphorus deficiency.

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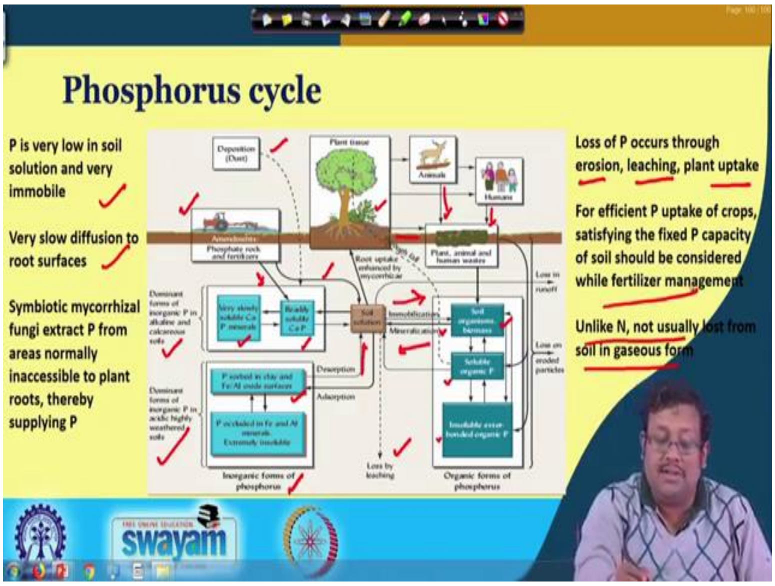

So, if you take a look in the phosphorus cycle it is very important. Now this is the phosphorus cycle; so let us start with the plant issue. So, when the plant dies ultimately you know when also the leaves it ultimately goes to the soil organisms, you know, and you know plant animal and human wastes. And also you know wastes are from animal is coming wastes from human is coming.

So, from their; obviously, it will be converted into soil organic biomass. From soil organic biomass there will be soluble organic phosphorus and also insoluble ester bonded organic phosphorus. So, these three soil organic organisms biomass soluble organic phosphorus and insoluble ester bonded organic phosphorus basically composed this organic forms of phosphorus in the soil. And also these soil organism biomass soluble organic P and this insoluble ester bonded to organic P are interchangeable among themselves.

So, and from this insoluble ester also you know phosphorus can move to the soil organic biomass. So, you know this soil organic biomass again mineralised to form different inorganic forms of phosphorus which comes into the soil solution; so this is the mineralization process we have already discussed the mineralization process while discussing the nitrogen and the opposite process is obviously, immobilization; where you can see that inorganic forms of phosphorus are being immobilized in the organic form.

And also soluble or from soluble organic phosphorus forms also they can come into the directly soil solution. So, this one way and finally, you can see soil solution from soil solution there are some losses by leaching. And obviously, those fraction which are present in the soil solution will be available for the plants you know to up take by root or different types of mycorrhizae, what are the mycorrhizae? We will discuss later on.

And also there are some deposition through dust. And also if we can apply the phosphatic fertilizer through phosphate rocks and other chemicals they directly helps in you know building this inorganic phosphorus in the soil solution. So, directly you can see here their a fraction of it coming directly into the soil solution. However, a major fraction is getting you know getting you know fixed by different chemicals. So, you can see a major fraction is coming in this way and there are some readily soluble calcium phosphate.

And obviously, there are some very slowly soluble calcium phosphate minerals. So, basically in a calcareous soil or in alkaline soil these phosphorus are fixed as calcium phosphate; this is the one of the major form. And in and dominant forms of inorganic phosphorus in acidic highly weathered soils are basically iron aluminium phosphate. So, in this case phosphorus sorbed in clay and iron aluminium oxide surface just like here. And also phosphorus occluded in iron aluminium minerals which are extremely insoluble.

So, these are basically inorganic forms of phosphorus you can see basically the inorganic forms of phosphorus are either iron or aluminium bounded phosphorus or the calcium bounded phosphorus. So, dominant forms are basically changes depending on the soil pH. So in acidic soil this iron aluminium phosphate predominant. However, as in case of in case of calcareous soil this calcium phosphate is predominant. However, from this soil phosphorus in clay and iron oxides and aluminium oxides there are some desorption occurs.

And as a result of desorption this basically goes to the soil solution. And opposite reaction opposite conversion is also happened when the soil solution H_2PO_4 for an HPO_4 get absorbed in this P in this clay and iron aluminium oxide surface. And ultimately get you know inaccessible to the plants creating deficiency So, phosphorus is very low in soil solution and very immobile.

Remember that it is phosphorus all very low and it as very slow diffusion to root surfaces. Whatever root is there; so very slow diffusion is their we require symbiotic mycorrhizal fungi to extract phosphorus from areas normally inaccessible to plant roots thereby supplying phosphorus we will discuss that later on. And unlike nitrogen not usually lost from the soil in gaseous form we know that.

And also we know soil loss of phosphorus occurs to basically erosion leaching and plant uptake. And for efficient P uptake of crops satisfying the phosphorus fixed phosphorus capacity of soil should be considered while fertilizer management. So, the fixation of phosphorus is very much important while considering the phosphorus management. So, this is the phosphorus cycle in a nutshell.

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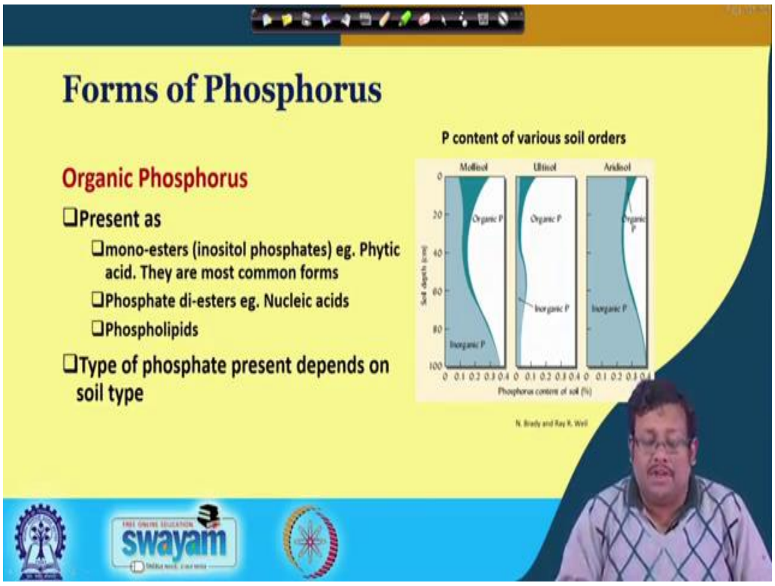

So, let us go ahead and see what are the different forms of phosphorus again. Obviously, in organic phosphorus are basically present as mono esters or inositol phosphates examples are; phytic acids. And they are most common in you know they are the most common organic forms of phosphorus. Apart from that phosphorus is present in phospholipids di esters like nucleic acids and sorry phosphate di esters like nucleic acids.

And finally, they are also present in phospholipids. And you know type of phosphate present depends on the; obviously, soil types. You can see here the phosphorus contain in different soils varies based on the soil type because in mollisoil you can see organic phosphorus concentration is higher at the surface. However, it gets layer at the you know at the depth of the at the you know at the sub soil whereas in case of ultisoil and aridisoil the comparatively less amount of organic phosphorus is present at the surface soil.

And you know also it get depleted in the surfaces you know sub surfaces soil. And inorganic phosphorus contain increases as we go to the lower depth specially in case of mollisoil and aridisoil. So, you can see based on the type of soil present they are also changing I mean the concentration of organic phosphorus and inorganic phosphorus changes with depth.

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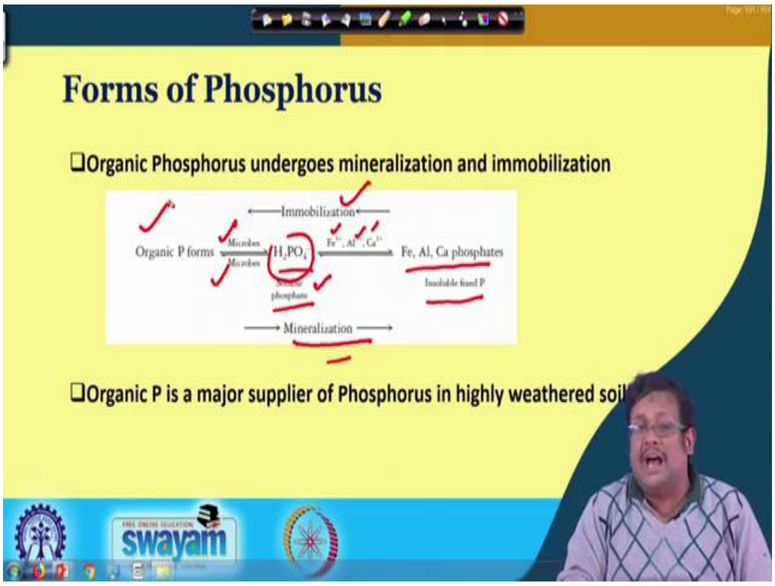

So, organic phosphorus basically undergoes mineralization and immobilization. You can see here organic phosphorus forms basically they are also you know converted to H_2PO_4 which is a soluble phosphate and this is a available form of phosphate.

And you know these basically conversion of organic phosphate to inorganic phosphate that it is called the mineralization process we know that. And this mineralization process again mediated by different microbes. And once this H_2PO_4 is formed they are getting fixed by either iron either aluminium or calcium to form this iron aluminium and calcium phosphate which are basically insoluble and fixed phosphate.

And opposite of the mineralization is immobilization where the some fraction of this fixed phosphates or you know inorganic soluble phosphates are converted into organic P forms. So, organic P is the major supplier phosphorus in highly weathered soil.

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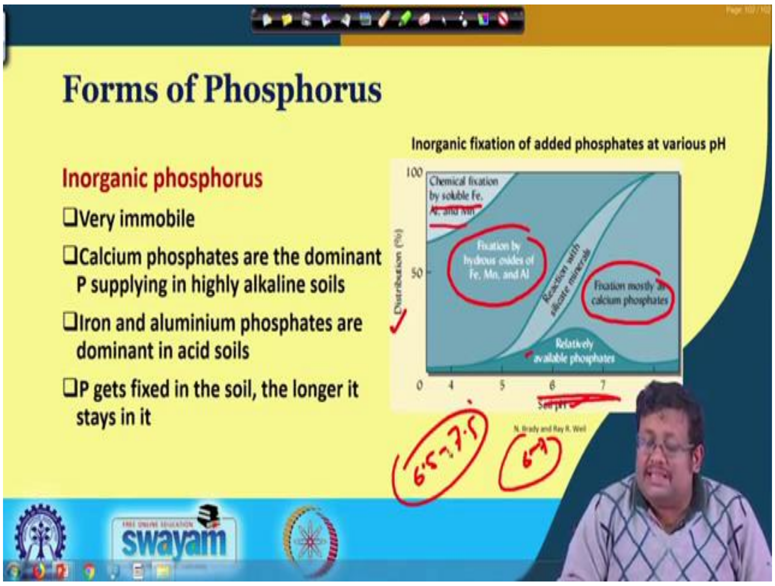

So, let us move a head and see what are the different chemicals fractions. Obviously, the inorganic phosphates are very immobile in nature and calcium phosphates are the dominant P supplying in highly alkaline soil we know that. And iron aluminium phosphates are dominant in acid soil. And phosphorus gets fixed in the soil and the you know the longer we you know we keep the phosphate phosphatic fertilizer or phosphorus into the soil it will get fixed.

So, you can see here it is the reaction relation between the soil pH and distribution and you can see as the soil pH goes towards the alkaline range. Obviously, fixation mostly as calcium phosphate and in the acidic range fixation is mainly by hydrous oxides of iron, iron manganese and aluminium. And some fraction in the extremist conditions you can see there are some chemicals fixation by soluble iron aluminium and manganese.

And relatively available phosphorus you can see here at the pH range of 6 to 7. So, this is the optimum range of phosphorus you know phosphorus availability. So, we know more precisely it is 6.5 to around 7.5 you can say. So, these are different chemical fractions which are present as inorganic phosphate form. So, let us move ahead and see; what is the influence of pH on different forms of phosphorus.

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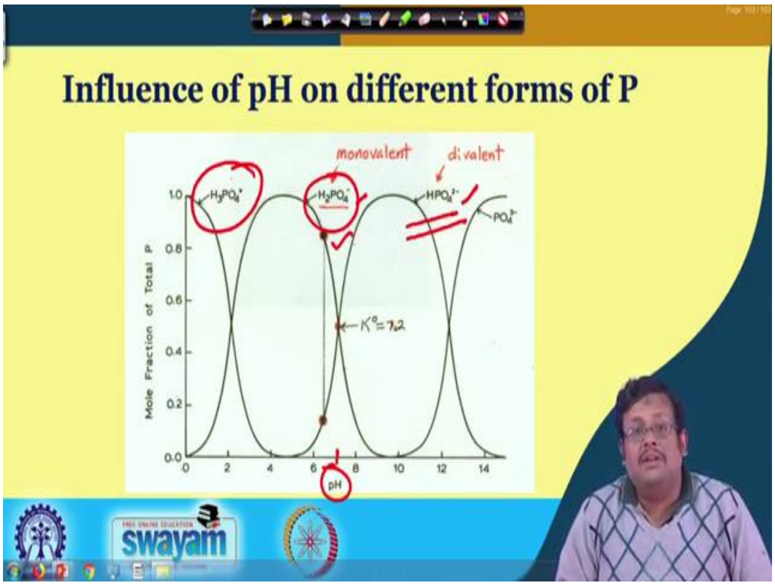

Obviously as we have seen that in the lower pH then; obviously, phosphorus will be mainly present as phosphoric acid form whereas, in case of high alkaline conditions in alkaline conditions it will present as divalent condition. And in the pH that is in available range starting from 6 to 7 around 6 to 7 it will be present an H_2PO_4 minus.

So, it is an H_2PO_4 form and this is a HPO_4^2 minus form. And at pH 7 point around I would say 7 to 7.5 these H_2PO_4 and HPO_4 are almost in you know equilibrium condition almost present in equilibrium condition. So, this is a primary orthophosphates and this is a secondary orthophosphates and those are you know available to the plants.

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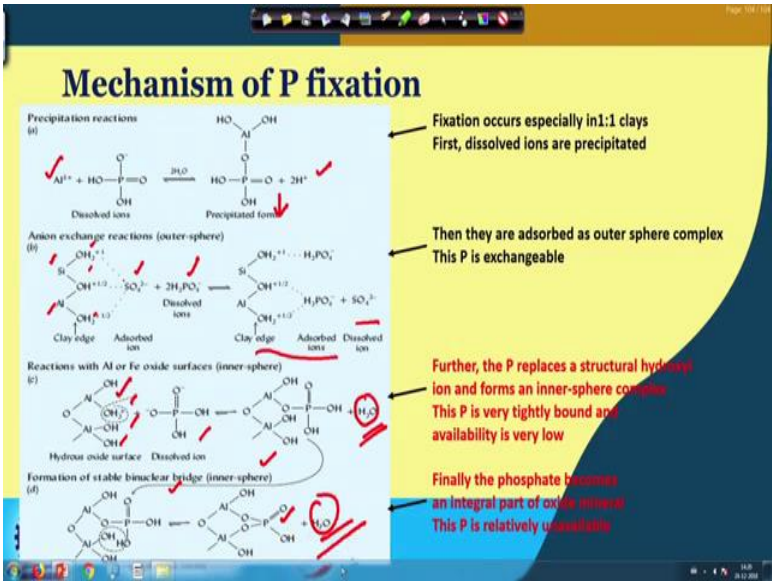

So, so let us see what are the different mechanisms of phosphorous fixation. So, one of the mechanisms is precipitation reaction and as you can see here these aluminium you know these basically fixation occurs specially in one is to one type of clays dissolved irons are precipitated. So, here the dissolved aluminium and you can see it is of you know phosphoric group.

And ultimately you know the protons are formed here and this are this chemical is getting you know precipitated. So, it is in one of the way of phosphorous fixation. Another way of phosphorous fixation is you can see here it is a clay silicon, aluminium and in the clay age you know that these hydroxyl groups are there. And these hydroxyl groups are basically you know due to the negative due to the positive charge development due to pH depended charge or variable charge they attract this negative charge sulphate.

And you can see this is a primary orthophosphates ion and this primary orthophosphates and basically exchange with this sulphate. So, bringing the sulphates to the soil solution and you can see here there is a formation of anion exchange reaction anion exchange outer sphere complex. So, this is an outer sphere complex. The third way is a formation of inner sphere complex a by reaction with aluminium and iron oxide surfaces.

So, you can see here again this is an you know clay age. And obviously, sorry hydroxide surface and obviously, there are hydroxyls and you know these H_2PO_4 or primary orthophosphates iron is here. And ultimately you can see these hydroxyl and one you know and these hydroxyl OH_2 and 1 H from here released as a form you know as you know water ultimately forming this compound.

And the second step there is a formation of binuclear stable binuclear bridge which is an inner sphere complex. So, basically in the stable binuclear bridge they are again you know there is a release of water ultimately it is a binuclear bridge you can see. So, this is another forms of fixation.

So, for the P replaces the structural hydroxyl ions and forms an inner sphere complex. And this P is very tightly bound and availability is very very low. And finally, the phosphate becomes an integral part of oxide minerals and this P is relatively unavailable in this case. So, now you have idea about the different mechanism of phosphate fixation.

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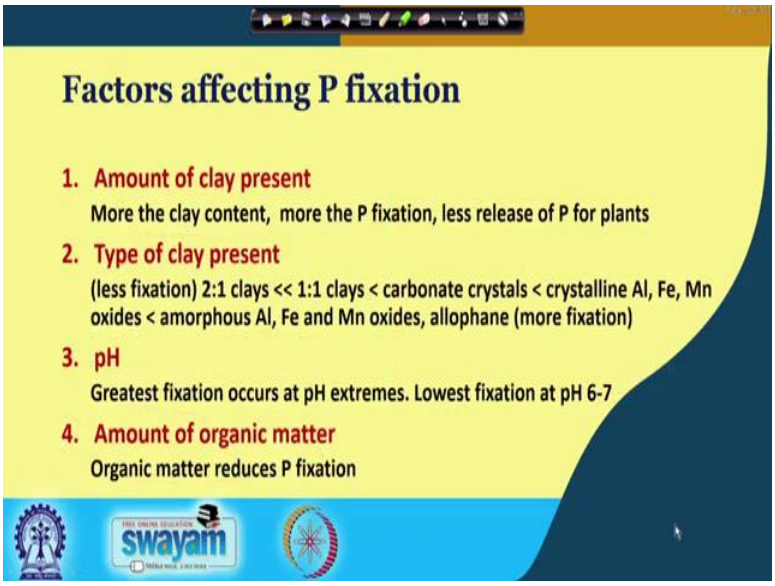

So, let us go ahead and see what are the different factors which effects the phosphate fixation. Obviously, the amount of clay present the more the clay present more the phosphate fixation and less release of phosphorous to the plant. Types of clay present; obviously, the most phosphorous fixation we will see in case amorphous iron aluminium manganese oxide and clay minerals like allophone.

And; obviously, the least fixation you will get in the two is to one type of clay. So, you can see a series of different minerals and you know the relative orders in which they can fix phosphate. And also pH in very important because greatest fixation occurs at pH extremes and lower fixation occurs at pH 6 to 7 which are optimum pH which is the optimum pH range.

And amount of organic matter obviously, the organic matter reduces phosphorous fixation because the different types of organic acids which releases due to the organic matter decomposition they can replace these fix phosphate from different iron aluminium and calcium phosphate. So, these are some benefits of organic matter and these are some factors which affect phosphorous fixation.

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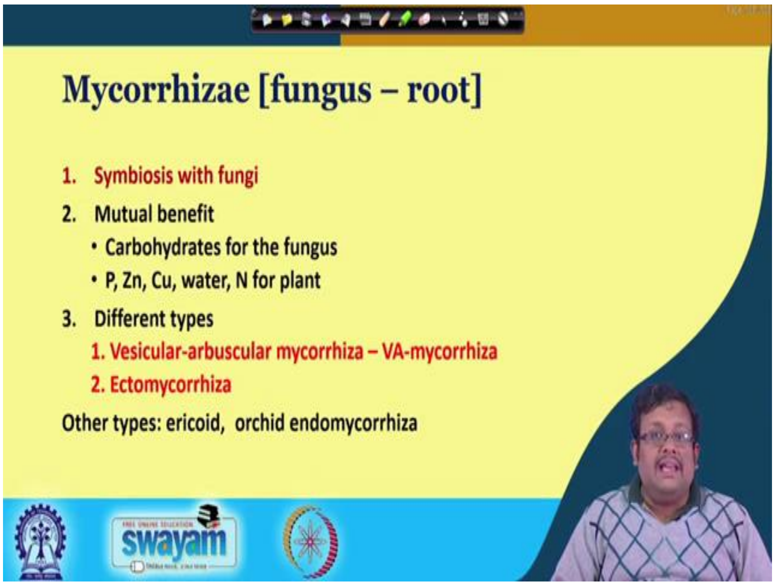

Now, let us see what are mycorrhizae. Now mycorrhizae is basically a symbiotic relationship between fungus and root of certain plants. Now that is why it is another name is myco. Myco term comes from the myco you know fungus and rhizae means root. So, it is basically symbiotic relationship between fungus and roots and they are mutually benefit as symbiosis is you know as there is a symbiosis.

Because carbohydrates you know you know plant you know fungus get carbohydrates from the plants. And also plant and plant get phosphorous zinc and copper water and nitrogen from the fungus; how? We will see. And there are two different types of you know mycorrhizae one is called the endomycorrhiza and ectomycorrhizal.

Among the endomycorrhiza very important one is vesicular arbuscular mycorrhiza or VA mycorrhiza or in short it is called VAM. And other type of mycorrhizaes are ericoid mycorrhizae orchid endo you know orchid endomycorrhiza so on so forth. But these two are major are you know and very very important; first of all the vesicular arbuscular mycorrhiza and you know ectomycorrhiza we will discuss them.

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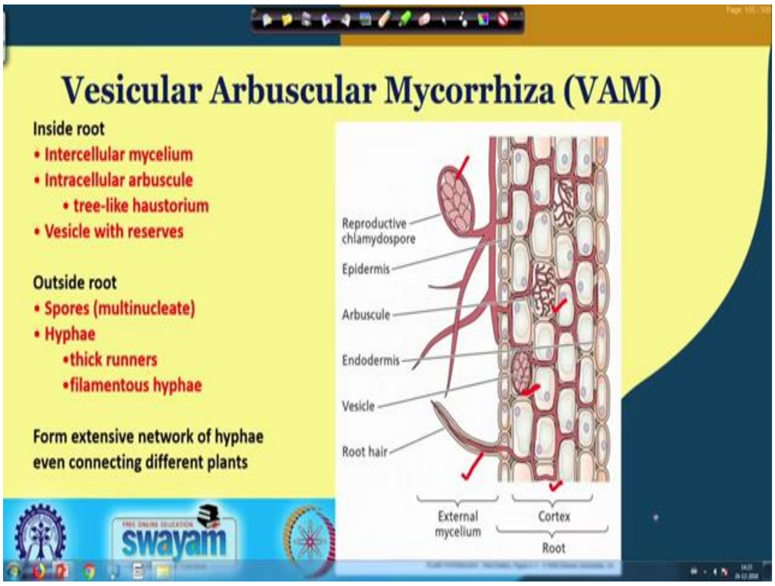

Now vesicular arbuscular mycorrhiza the short form is VAM. And you can see here in the inside root; obviously, they can form different types of intra intercellular mycelium. So, this is a you know this is basically external mycelium and you can see this is a internal mycelium. So, they are any basically penetrating within the cell and they are intercellular mycelium.

And then intra you know intracellular arbuscules. So, these are arbuscules and basically you know tree like haustorium used for nutrients swapping between the plant cell and the mycorrhizae and between the fungus. And obviously these are some structures we call them vesicles which contain basically the results. And outside the root you will see some you know spores which are basically multinucleate basically they are reproductive chlamydospore.

And also hyphae you can see here these are these are basically thick runners and filamentous hyphae. And these basically the outer sphere and inner you know inner inside root and outside root they basically forms an extensive network of hyphae even connecting different plants. So, this is what we call VAM or vesicular arbuscular mycorrhiza.

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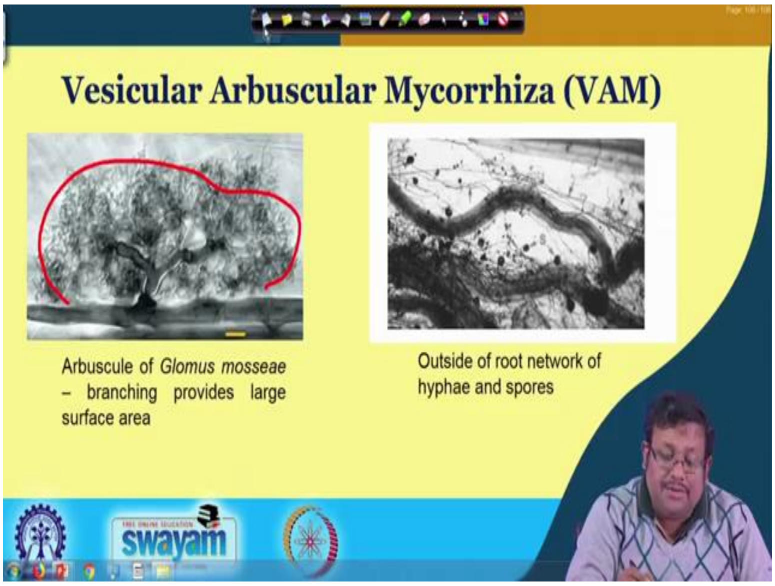

Now, some examples you know some photographs of VAM as you can see this is an arbuscule of Glomus species where you can see extensive branching provides large amount of surface area through which nutrients can be exchanged. And also this is an outside root network of hyphae and spores you can see how intricate network of this hyphae and spores can be developed. So, this mycorrhizal association.

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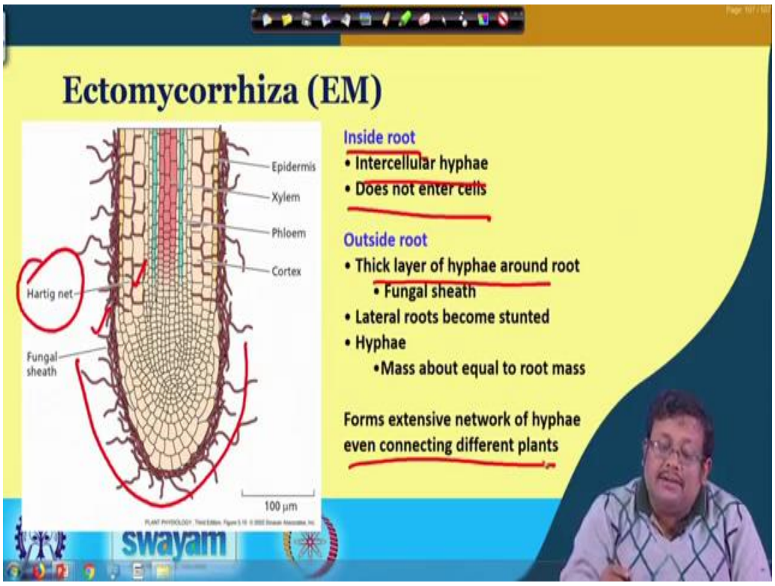

So, another important mycorrhizae is ectomycorrhiza or EM. And this ectomycorrhiza you can see inside root I mean the name suggest that they are outside basically present in outside. And you can see inside root they are basically forms intercellular hyphae and where they do not enter into the soil just like the VAM or endomycorrhiza did. Because they forms this arbuscules within the cell.

However, they only form this intracellular hyphae and this intracellular hyphae called net like structure you know forms this net like structure we call it hartig net. And outside root you can see thick layer of hyphae around the root and they are calling the fungal sheath and this lateral roots becomes stunted.

And this is you can see this is the fungal sheath; obviously, hyphae also mass about equal to root mass forms extensive network of hyphae even connecting different plants. So, this is an ectomycorrhizal fungi.

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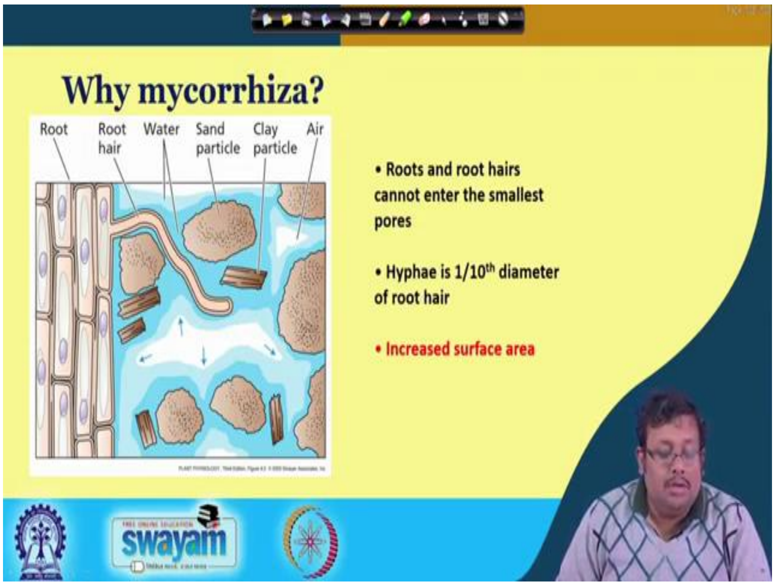

So, why we need mycorrhiza? Well you can see here the roots and root hairs cannot enter into the smallest pores for extraction of the nutrients. Especially in and this is very much important so and this extraction is very much important in nutrients limited conditions. Especially where the nutrients is deficient or nutrient is fixed.

So, you need some mechanism to extract those nutrients from some smaller spores. Now, the mycorrhizal fungi are one tenth of diameter of the root hair. So, they can easily penetrate into the into different into very small you know pockets and they have increase surface area. So, they can easily extract the nutrients from different pockets or different places where the roots are basically cannot access. So, that is why we need mycorrhizal association especially in nutrient rich environment.

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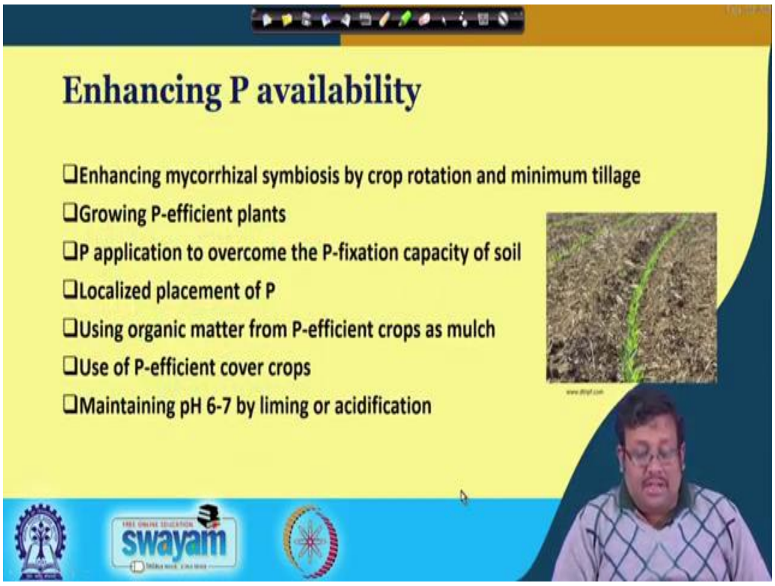

So, how we can enhance the phosphorous availability to the plant? Now enhancing mycorrhizal symbiosis by crop rotation and minimum tillage is one of the way to enhance the phosphorous availability. And also growing phosphorous efficient plants which can withstand low amount of phosphorous. And also phosphorous application to overcome the P fixation capacity of the soil, localized placement of the soil, you can see band placement of phosphorous is you know is done.

Basically they are placed in bands around the root of the plant around the or around the plant. So, that the phosphorous has not you know you know if the less amount of reactive surface of clay is available for the phosphorous. So, that is why you know the band placement for phosphorous is recommended and also using organic matter form P, P efficient crop as mulch. And also use the phosphorous efficient cover crops and maintaining pH 6 to 7 by liming and acidification are some examples by which you can enhance the phosphorous availability.

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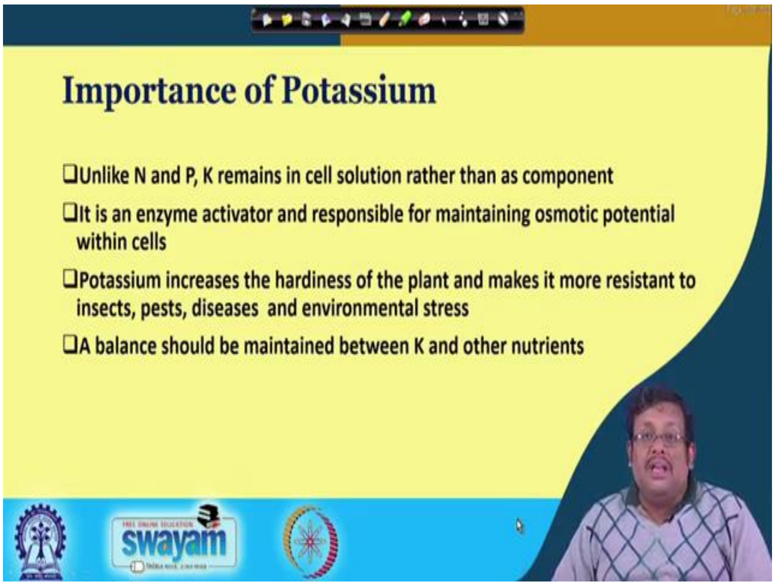

Now, let us start with the potassium. Unlike nitrogen and phosphorous potassium remains in cell solution rather than as component. Now it is enzyme activator and responsible for maintaining osmotic potential. Remember phosphorous is taken up by the plant as K plus.

I am sorry potassium is taken up by the plant as K plus. Now potassium increases the hardiness of the plant and makes it more resistant to insects pests and diseases and environmental stress and remember a balance should be maintain between potassium and other nutrients.

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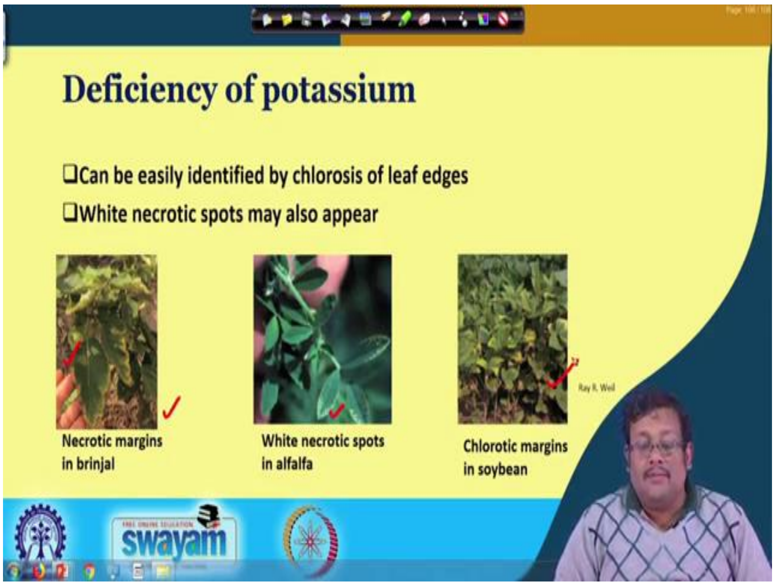

So, basically it is involved in different types of activation of enzymes. Now deficiency of potassium is important because it can be easily identified by chlorosis on leaf edges. So, you can see here and also white necrotic spot may also appear.

So, you can see here necrotic margin in brinjal. And; obviously, white necrotic spots you can see here in alfaalfa and also chlorotic margin in soyabean. So, all these are deficiency symptoms of potassium.

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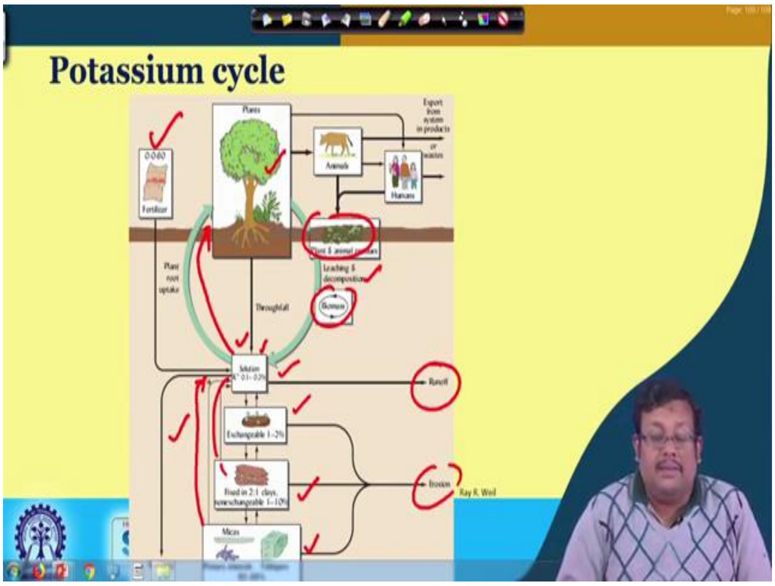

So, what is the potassium cycle? So, you can see here this is the potassium cycle; obviously, the plant is the you know plant is there over the surface. And when the plants and different types of animals residues goes as a you know general you know builds up they goes to leaching and decomposition and ultimately produces the biomass.

From this biomass soil solution phosphate soil solution potassium basically came which is present in only 0.1 to 0.2 percent. And from there you can see exchangeable form which is 1- 2 percent and fixed in 2 is to 1 types of clays that is non exchangeable 1 to 10 percent. And finally, micas and other you know elements are present which are 90 to 98 percent.

So, this exchangeable fixed and you know mineral forms of phosphate get easily you know easily removed through erosion. And you know potassium which is present in soil solution get lost by run off. So, plant basically takes up the potassium from this solution which contains 0.1 to 0.2 percent and also we add different types of phosphoric fertilizer like MOP SOP we will discuss that later on. And these basically generates the potassium in the soil solution.

Sometime these solution P also get you know lost by leaching process. And conversion of solution to exchangeable and exchangeable to non exchangeable and non exchangeable to primary mineral fixed, are basically reversible processes and when the solution phosphate solution potassium is getting depleted. Sometime this non exchangeable forms of potassium get to the solution. And then sometime this you know mineral or you know mineral primary mineral fixed potassium goes to the soil solution, but soil solution to replain, is that, but the process is very very slow.

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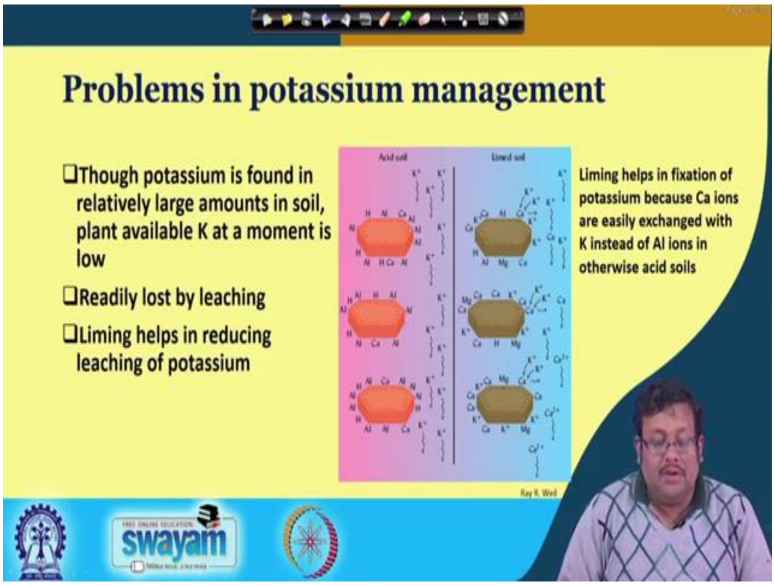

So, what are the problems in potassium management? Well through potassium is found in positively large amount you know they you know the potassium is present in large amount in the soil. However, it is plant available form is very you know relatively low because it readily lost by leaching.

So, liming helps in reducing leaching in potassium why? Because you can see here there are two type of soil one is acid soil and limed soil. So, liming helps in fixation of potassium because calcium ions are easily paste exchangeable with potassium and instead of aluminium in otherwise acid soils so in aluminium in acid soil. Obviously, the exchangeable sides are exchange complex will be saturated by aluminium. So, and in case of alkaline soil the exchange complex would be saturated by calcium.

But calcium can easily replaced by potassium so there by it get fixed. However, aluminium cannot be easily replaced by potassium. So, that is why liming helps in reducing the phosphate potassium you know leaching.

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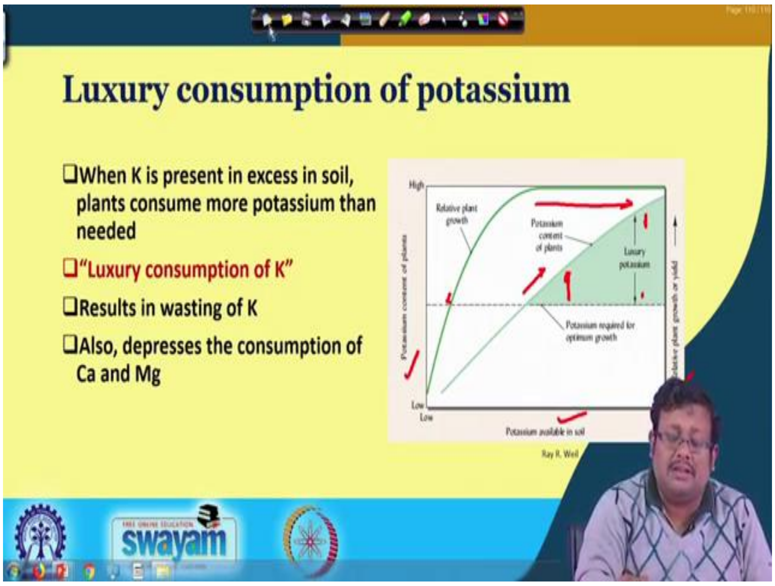

So, what is the luxury consumption of potassium luxury consumption is when the potassium is present in excess amount in soil. And plant consumes more potassium than needed and that is called the luxury consumption of K. So, you can see here this is a relations between potassium available to the plant and potassium content of plants. And this is the in the secondary y axis this is the relative plant growth or yield.

So, we can see as we are increasing the potassium available potassium in the soil and potassium content of the plant is getting increased obviously in this direction. However, this line basically shows the potassium required for optimal growth. So, above which all these are basically luxury consumption which are basically not needed.

So, similarly you can see the plant will response to the added potassium up to this level. And after that you know the rate of increase will decrease and ultimately it will reach a plato where there is no further relative growth of the plant. So, this is called the luxury consumption of potassium.

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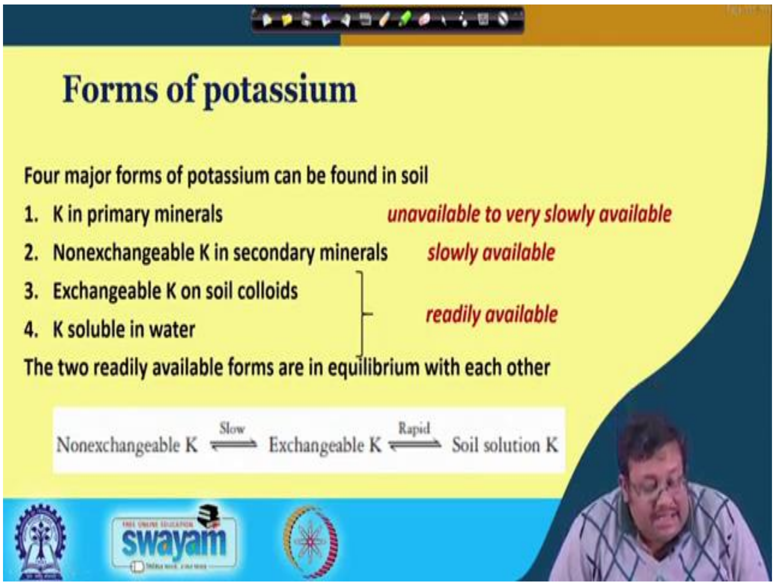

So, what are the different forms of potassium; we have already seen. Four major forms of potassium are found in the soil. Potassium in primary minerals, which are unavailable to very very slowly available, then secondly, non exchangeable potassium in secondary minerals which are also slowly available; then third, is exchangeable potassium on soil colloids then potassium soluble in water.

And these two are readily soluble in for plants. And the two readily available forms are in equilibrium with each other. So; obviously, non exchangeable potassium to exchangeable potassium conversion process and it is reverse process is very slow. However, the conversion of exchangeable form to soil solution potassium and it is reserve process is fairly rapid.

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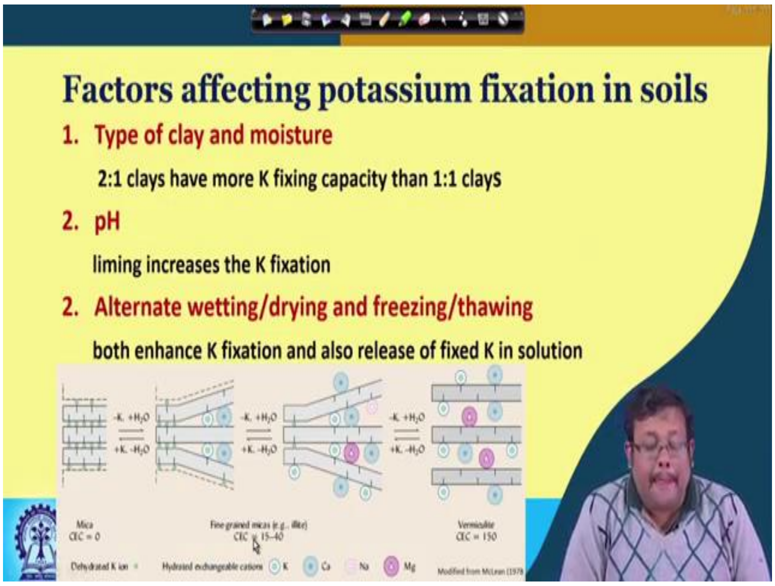

So, what are the factors which affects potassium fixation in the soil? Type of clay and moisture is very very important. So, two is to one type of clay have more potassium fixation capacity then one is to one type of clay. And secondly pH as you know that pH you know liming increases the potassium fixation. And alternate wetting and drying and freezing and thawing you know during our clay mineralogy discussion.

We have discussed that how due to how this potassium are getting fixed in the inter layer space of mica. And from this mica or fine grained mica in illite how due to different types of weathering process these interlayer potassium get replaced by manganese. And ultimately the produce the ultimately produce the vermiculite. So, this is how and this conversion of mica to vermiculite basically made through alternative wetting and drying or freezing or thawing process so that is being shown here.

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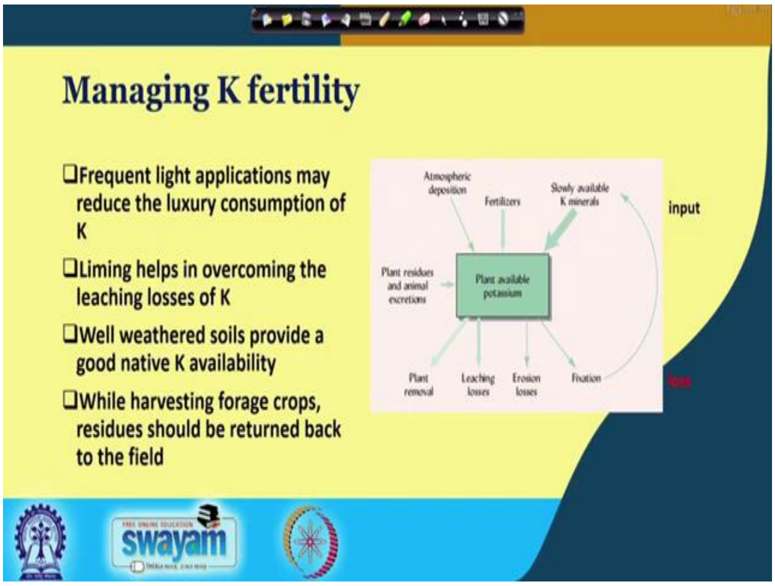

So, also it is a last slide. So, managing potassium fertility; obviously, it is a frequent light application may reduce the luxury consumption of potassium. And also liming helps in overcoming the leaching losses of potassium. Well weathered soil provides a good native potassium availability. And finally, while harvesting the forage crops residues should be returned back to the field so that there is a continuous supply of potassium.

So obviously these are four different ways of inputs of potassium; obviously, plant residues and animal excretions. And you know atmospheric depositions fertilizers slowly available potassium minerals whereas, the losses are fixation, erosion losses, and then leaching losses and plant removal. Obviously this fixation also goes to slowly available potassium minerals because they are intern also very slowly available to an ultimately helps in building the potassium concentration in the soil solution.

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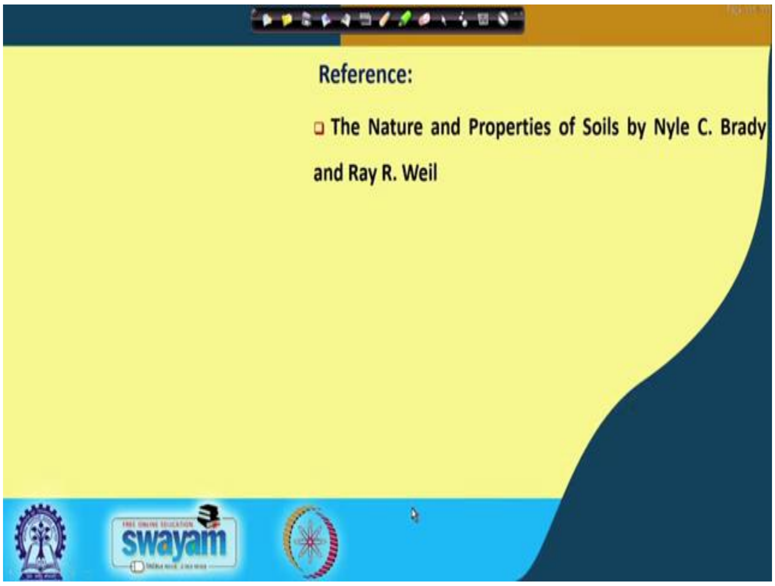

So, guys we have finished this lecture. And this reference is again The Nature and Properties of Soil by Nyle C. Brady and Weil. And I hope that you have learnt something new in this lecture about potassium and phosphorous. And let us stop here and we will start fertilizer in our next lecture.

Thank you.