Soil Fertility and Fertilizers
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Week 3
Lecture 12
Soil P and K Plant Nutrition (Contd.)

Welcome friends to this lecture 12 of NPTEL online certification course of soil fertility and fertilizers. And we are at week 3 and in this week, we are talking about soil phosphorus and potassium for plant nutrition.

So, in our previous lecture of this week, we have discussed about soil phosphorus and their origin, and what are the forms of soil phosphorus in soil like organic forms, then inorganic forms, what does, what are the other, what are the important organic forms of soil phosphorus, and what are the combined forms of inorganic soil phosphorus, what are the ions which are present in soil and what are the important soil phosphorus ions, which plant can uptake, we have discussed about the primary orthophosphate ions, secondary orthophosphate ions.

We have discussed about the phosphorus cycle in soil. We have seen, how phosphorus can move from organic pool to inorganic pool, and from there it can either adsorbed, or precipitate in other forms. They can precipitate in secondary forms and can produce different types of minerals like calcium phosphate, they can also precipitate in the forms of aluminium phosphate, iron phosphate, they can adsorbed onto the surface of the clay minerals, or iron aluminium oxides.

And, these iron, these primary, and secondary orthophosphate ion can also originated from the weathering of appetite minerals, we have discussed about the appetite minerals, they are the major source of these phosphate ions in the soil. And, we have also discussed the iron, and aluminium bond forms, and calcium bond forms of phosphate.

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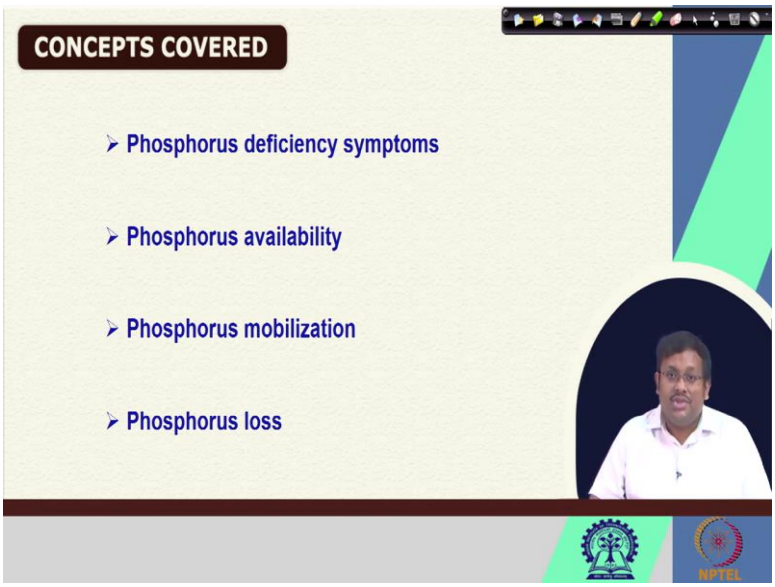

So, in this lecture, we are going to discuss these important concepts. We are going to discuss the phosphorus deficiency symptoms in plants, we are going to discuss about phosphorus availability to the plant, and then phosphorus mobilization in the soil. And also, we are going to discuss how phosphorus can be lost from the soil.

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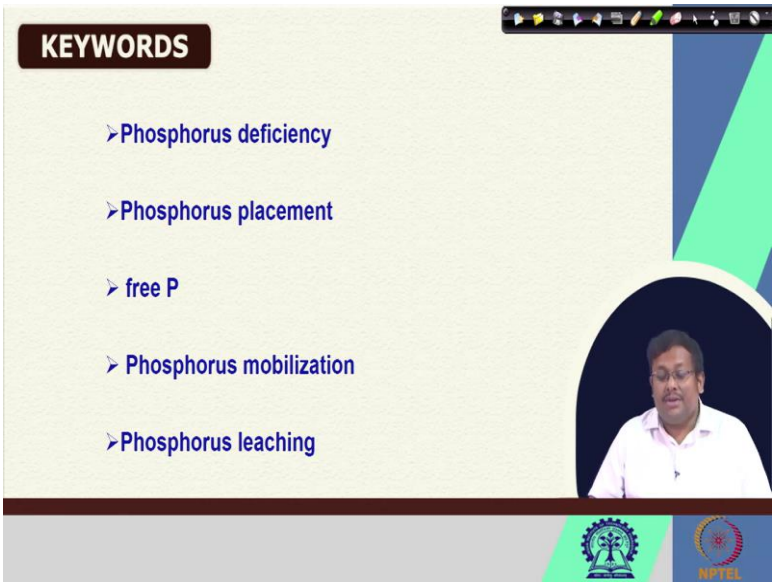

So, these are some of the key words of this lecture like phosphorus deficiency, phosphorus placement, free phosphorus, phosphorus mobilization, and phosphorus leaching. So, these are some of the key words of this lecture.

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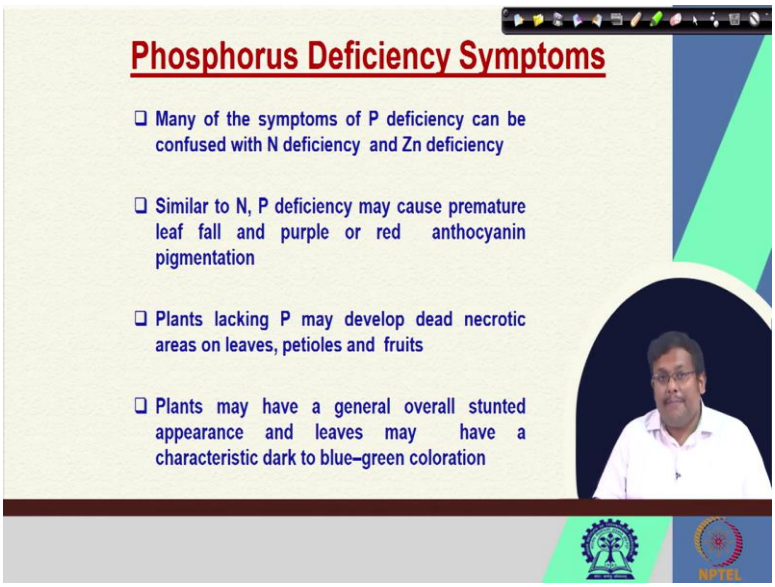

So, let us start. So, at first, we should understand what are the major deficiency symptoms of phosphorus in plants. Now, we have discussed that plants get their energy from the phosphorus, and phosphorus is declared for their growth because they help in the formation of new tissue.

So, many of the symptoms of phosphorus deficiency, we can see visually by the stunted growth of the plant, but at the same time we should be very-very cautious, because many of the symptoms of phosphorus deficiency can be confused with nitrogen deficiency, and zinc deficiency. Now, how? Because similar to nitrogen, phosphorus deficiency may cause premature leaf fall and purple or red anthocyanin pigmentation.

So, in case of nitrogen you will also we have seen that there is a premature leaf fall, and purple, or red anthocyanin mutations is the, in case of phosphorus also we can see that. Plant lacking phosphorus, may develop dead necrotic areas on leaves, petioles, and fruit. And plants may have a general overall stunted appearance, and leaves may have a characteristic dark to blue-green coloration. So, these are the major symptoms of phosphorus deficiency in plant.

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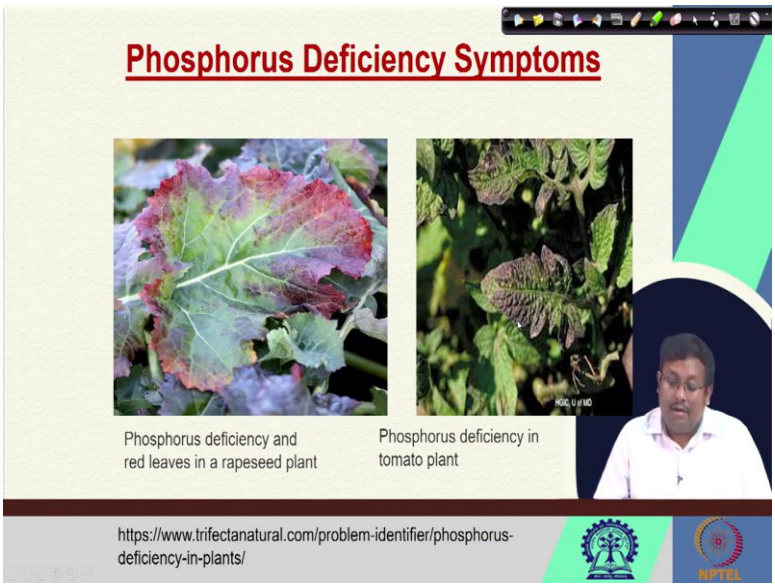

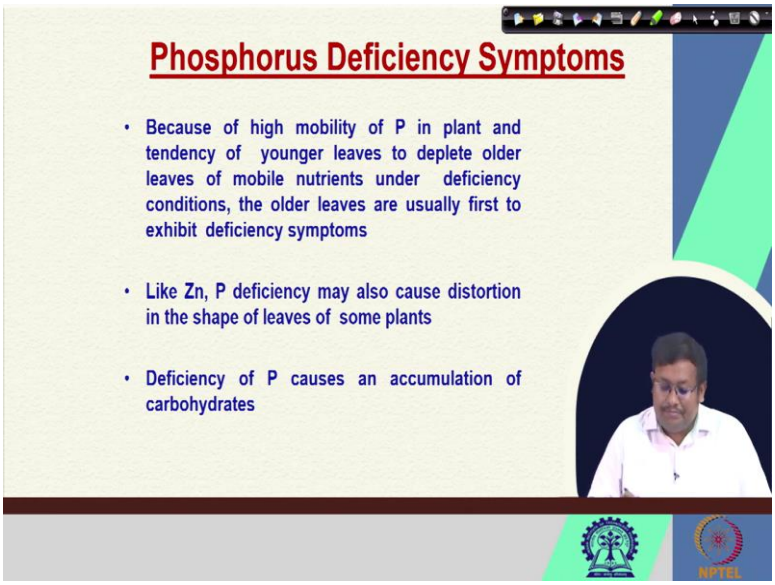

So, if you can see some of these, you can clearly see here in this picture, that this is phosphorus deficiency in rapeseed plant. We can see there is a clear red leaf, which shows the phosphorus redness in these edges of this leaf, which can show the phosphorus deficiency. Also, you can see this is the phosphorus deficiency in tomato plant, you can clearly see this redness in the leaf edges. So, these is one of the major deficiencies in terms of the phosphorus deficiency in plant.

So, because of high mobility of phosphorus in plant, and tendency of younger leaves to deplete older leaves of mobile nutrients under deficiency conditions, older leaves are usually first to exhibit deficiency symptoms. Just like in case of nitrogen, we have seen in case of phosphorus also the, we can see the deficiency symptoms appearing in the older leaves, first

appearing in the older leaves. Because phosphorus is highly mobile in plant and so, that is why the deficiency symptoms can be first seen in case of older leaves. Like zinc, phosphorus deficiency may also cause distortion in the shape of the leaves of some plants. And, deficiency of phosphorus causes an accumulation of carbohydrates.

So, if you can see if you can go back to the previous slide, we can see, you can see clearly some deformation of the leaf shape. So, this is another important symptom of phosphorus deficiency in the plant, which can be easily confused with zinc deficiency because, in case of zinc deficiency also, there will be some distortion in the shape of the leaves.

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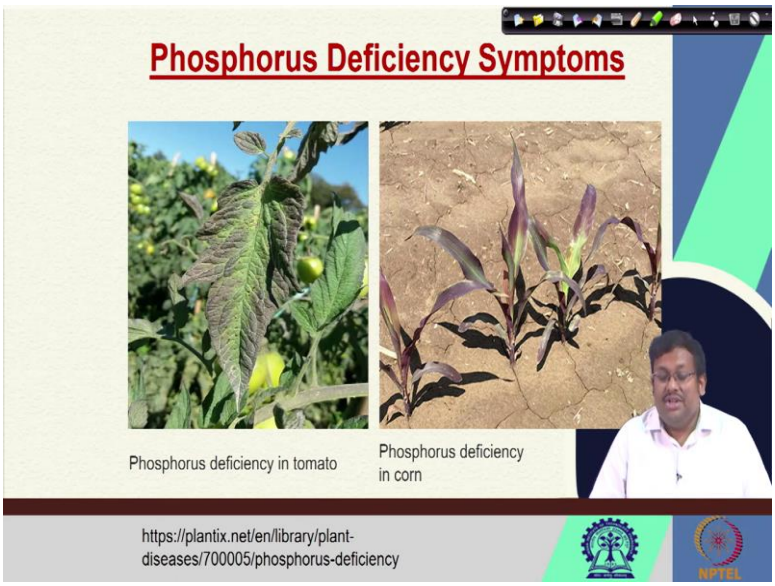

Here, you can see the phosphorus deficiency symptom in case of tomato, we can clearly see reddish, red coloration of the leaves. And here, you can see phosphorus deficiency symptoms apart from this redness in the leaves, we can see their stunted growth. So, this is one of the most important deficiency symptoms of phosphorus in plant.

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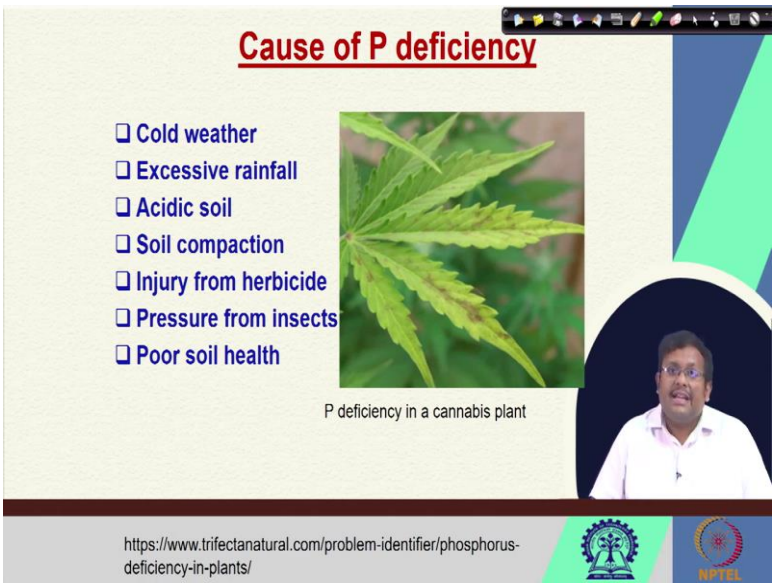

Now, what are the causes of phosphorus deficiency? There are certain causes of phosphorus deficiency. First of all, cold weather is easy one of the major factor of phosphorus deficiency, excessive rainfall is another important as the cause of phosphorus deficiency, acidic soil can cause phosphorus deficiency because in case of acidic soil, phosphorus will be precipitated in iron phosphate, or aluminium phosphate, and thus become unavailable to the plant.

Soil compaction is an another important factor of phosphorus deficiency, injury from herbicide can cause phosphorus deficiency, pressure from different insects and also cause phosphorus deficiency, and finally poor soil health. The soil which is devoid of organic matter can also cause phosphorus deficiency.

Because organic matter, the presence of organic matter can improve the phosphorus mobilization, or I would say the dissolution of adsorbed phosphorus can be mediated by the presence of organic matter, and that is why if the soil health is poor that means, the organic matter content is poor that can also cause phosphorus deficiency.

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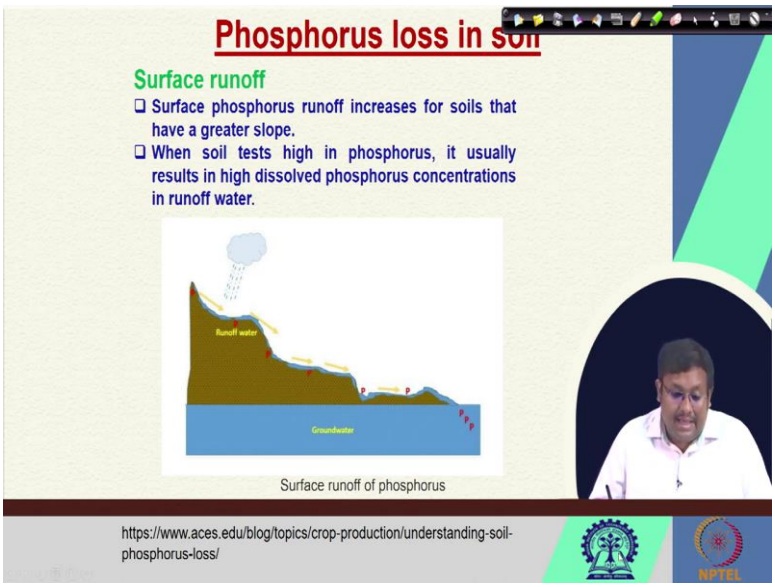

Now, phosphorus also get lost from the soil through different process just like nitrogen. One of them is surface runoff. So, here you can see that surface phosphorus runoff increases for soils that have greater slope. Of course, here you can see the greater slope will have higher runoff, and when soil tests high in phosphorus it usually results in high dissolved phosphorus concentration in runoff water.

So, when there is a surface runoff that can, the phosphorus can easily move from soil to the groundwater, and can create different types of problems just like eutrophication. So, they can go to the water bodies and create eutrophication and phosphorus can also go to the groundwater also. So, the surface runoff is one of the major processes through which phosphorus gets lost from the soil.

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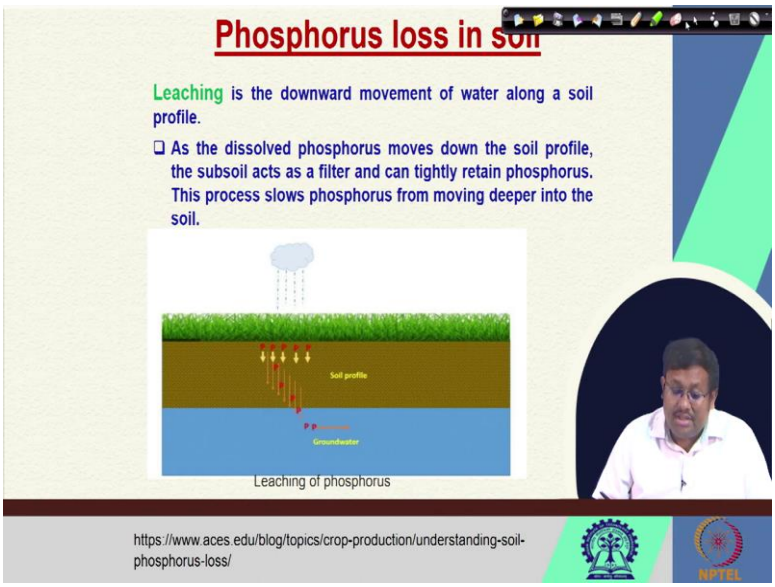

Another important process is leaching process. So, you know that leaching is a downward movement of water along a soil profile. So, as the dissolved phosphorous moves down the soil profile, the sub soil acts as a filter and, can tightly retain phosphorus this process slows phosphorus from moving deeper into the soil. So, here you can see, when there is a move when the phosphorus moves down to the soil profile, the soil profile acts as a barrier or filter that can tightly retain this phosphorus and ultimately, this process slows phosphorus from moving deeper into the site. So, this is another important process of phosphorus loss.

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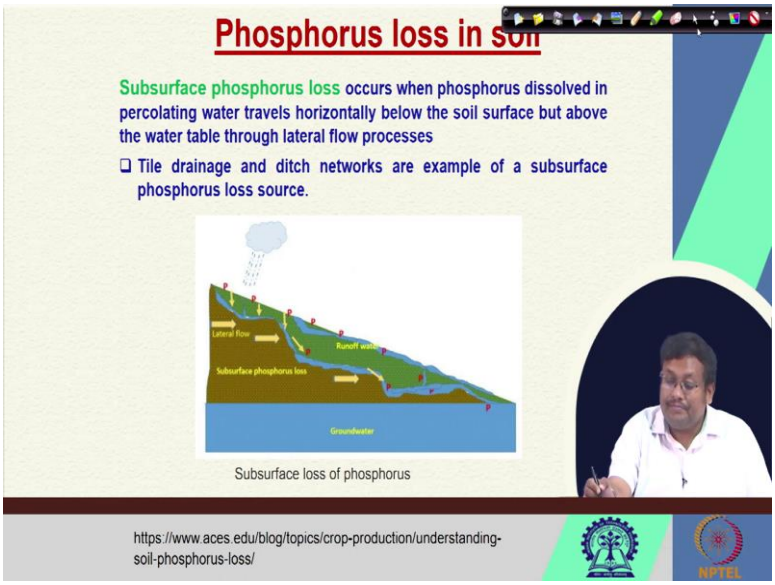

Subsurface phosphorus loss occurs when phosphorus dissolved in percolating water, travels horizontally below the soil surface, but above the water table through lateral flow process.

So, here in this picture, you can clearly see that, here the phosphorus is moving in percolating water, this is a you can see percolating water horizontally below the soil surface, but above the water table, so, what a table is here, so, above the water table, but below the soil surface through lateral flow process.

So, here you can see through lateral flow process these phosphorus get moved from the soil to the water bodies. And tile drainage and ditch drainage at the examples of a subsurface phosphorus loss source. So, the subsurface phosphorus loss generally occurs when there is a tile drainage and ditch networks are there. So, this is another way through which the phosphorus get generally lost from the soil apart from leaching and surface runoff.

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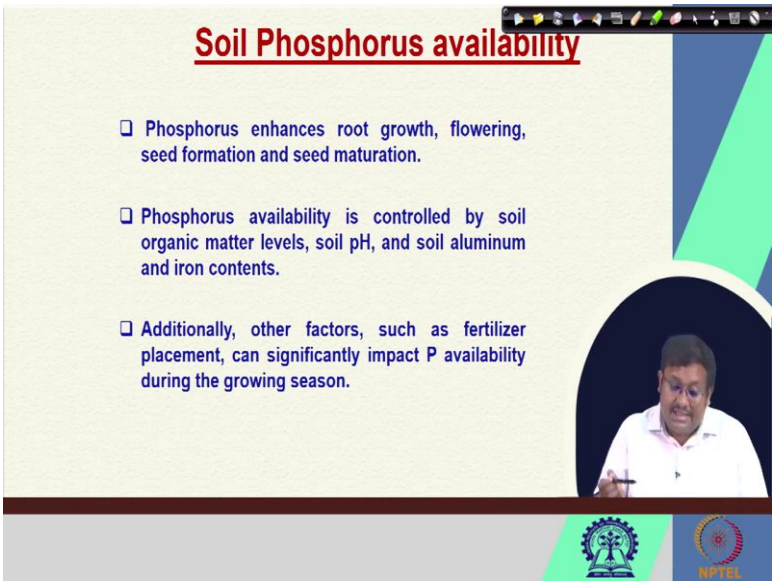

Now, if we see the availability of the soil phosphorus. Phosphorus enhances root growth, flowering, seed formation and seed maturation. And phosphorus availability is controlled by soil organic matter levels, soil pH, soil aluminium and iron contents. Of course, when there is a high content of soil aluminium and iron, especially in acidic soil that will enhance the phosphorus precipitation in the forms of iron and aluminium phosphate. However, when the pH of the soil goes towards neutral, then phosphorus availability increases. Additionally, when there is organic matter, that can also improve the dissolution of adsorbed phosphorus and thereby improving their availability to the plant.

Apart from that other factors such as fertilizer placement can significantly impact phosphorus availability during the growing season. Since phosphorus, when you apply the phosphorus into the soil, most of it gets bond to the soil solid phases, and thus become unavailable. So,

phosphorus placement in the soil during the growth of the plant is a very important consideration. So, we are going to discuss this also in our upcoming slides.

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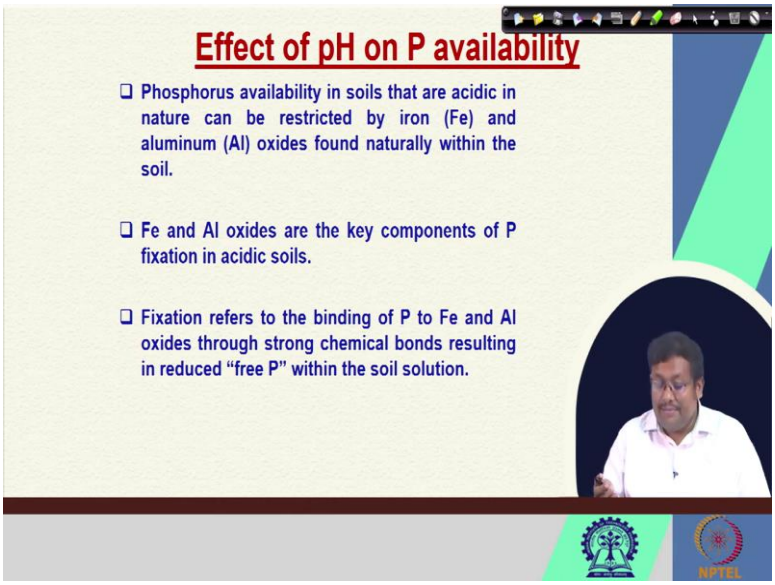

So, phosphorus availability in soils that are acidic in nature can be restricted by iron, and aluminium oxides found naturally within the soil. So, we have already seen that when there is an iron and aluminium oxides in the soil that can produce, that can precipitate that first phosphorus from the soil solution, the primary orthophosphate and, primary orthophosphate ions.

So, that creates the phosphorus deficiency in the soil. Iron aluminium oxides are the key components of phosphorus fixation in acidic soil. Of course, as we know that when in acidic soil, of course, are also in alkaline soil also, phosphorus get fixed in calcium phosphate. In acidic soil they get fixed in, phosphorus gets fixed in as iron phosphate, or aluminium phosphate.

Fixation refers to the binding of phosphorus to iron and aluminium oxides through strong chemical bond resulting in reduced free phosphorus within this solution. Remember, whatever phosphorus uptake in a plant uptake phosphorus from the soil solution that depends on those two major ions, as we have discussed primary orthophosphate ion, and secondary orthophosphate ion.

When these two major forms get fixed by phosphorus by iron and aluminium, their concentration in the soil solution is depleted. And as a result, there will be a deficiency and

plant cannot further uptake these ions from the soil solution because there will be less free phosphorus, available phosphorus iron in the soil solution.

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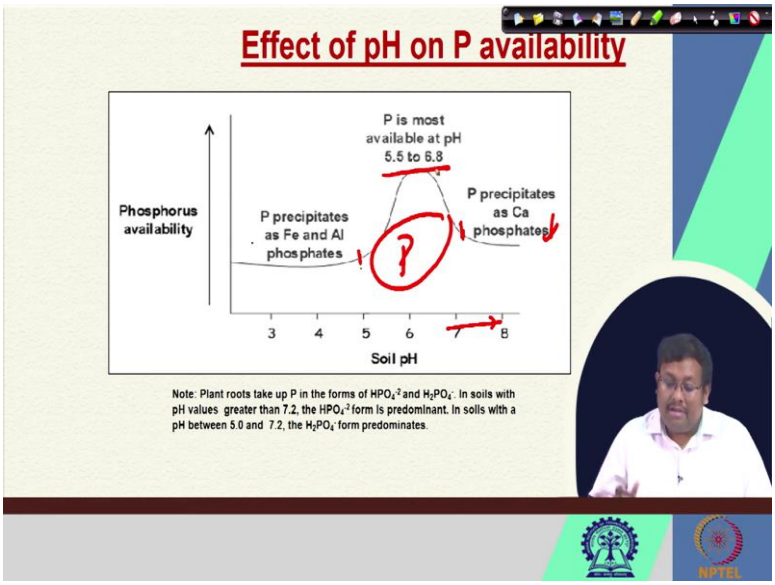

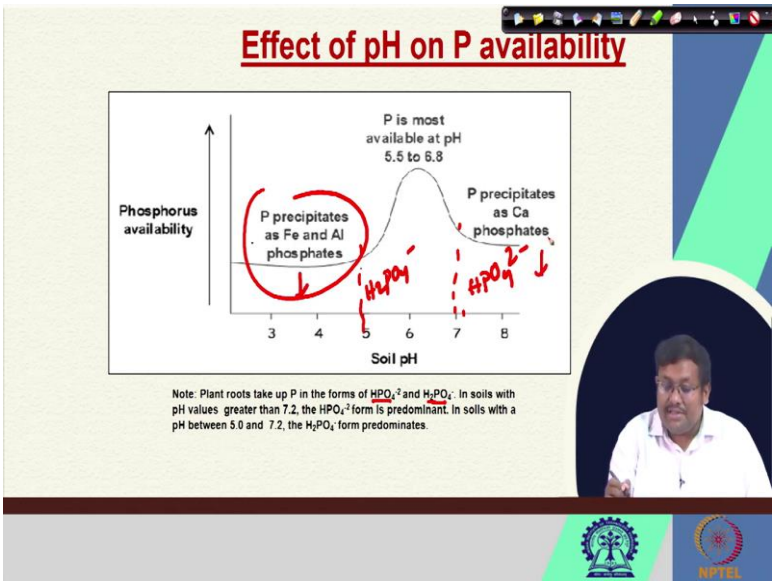

So, that is why the pH plays an very, very important role in the overall phosphorus availability, pH is the major controlling factor of phosphorus availability in the plant. So, you can see here clearly in the y axis, there is phosphorus availability, and in the x axis there is soil pH. Phosphorus precipitates as iron, and aluminium phosphate when the pH up to 5. And when the pH goes towards neutral that is from 5.5 to 6.8 in this zone phosphorus is mostly available, and again when the pH goes beyond 7, then phosphorus precipitates as calcium phosphates and then become have again unavailable to the plant.

So, optimum pH range where phosphorus is available to the plant lies in between 5.5 to 6.8, where the concentration of both ions, primary orthophosphate ion, and secondary orthophosphate ion are at equilibrium. They are at equilibrium, and plant can uptake these ions in optimum quantity.

So, here you can see that plant roots take phosphorus in the forms of HP04 2 minus, H2PO4 minus in soils with pH greater than 7.2. The HP04 2 minus form is predominant. In soils with pH between 5 and 7.2 the H2PO4 ion predominates. So, the pH basically controls the phosphorus availability by controlling the precipitation of phosphorus either in the form of iron, and aluminium phosphates, or calcium phosphates.

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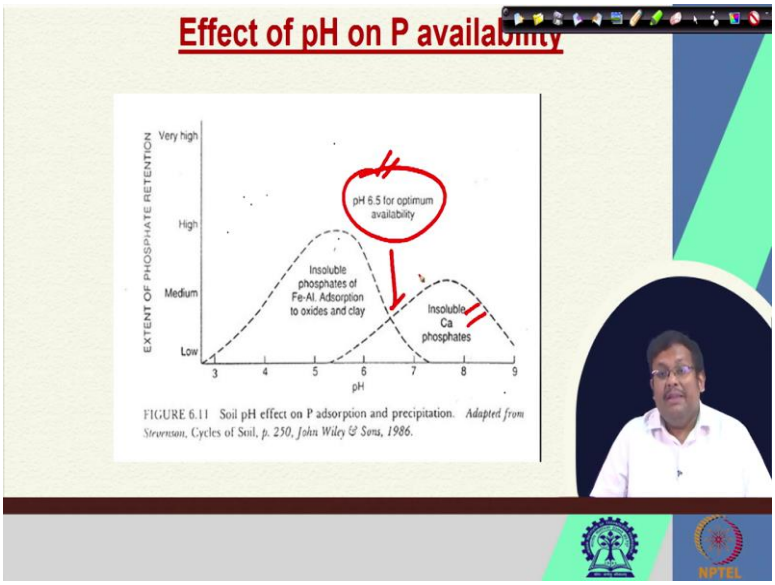

So, we can also see here there is another graphical representation, you can see extent of phosphate retention in the y axis and pH in the x axis. So, you can see here when the pH is from up to this range around in the acidic condition. So, the insoluble phosphates of iron, aluminium adsorption to oxides and clay. So, that means extent of phosphate retention is quite high, when there is low pH and of course, when there is a high pH insoluble calcium phosphates retention is also phosphorus retention is also high.

So, here pH 6.5 for optimum availability. So, if we have to pin down a particular pH for optimum availability that would be around pH 6.5, where the availability or the phosphate retention is minimum. So, that shows the importance of controlling the pH for phosphorus availability to the plant.

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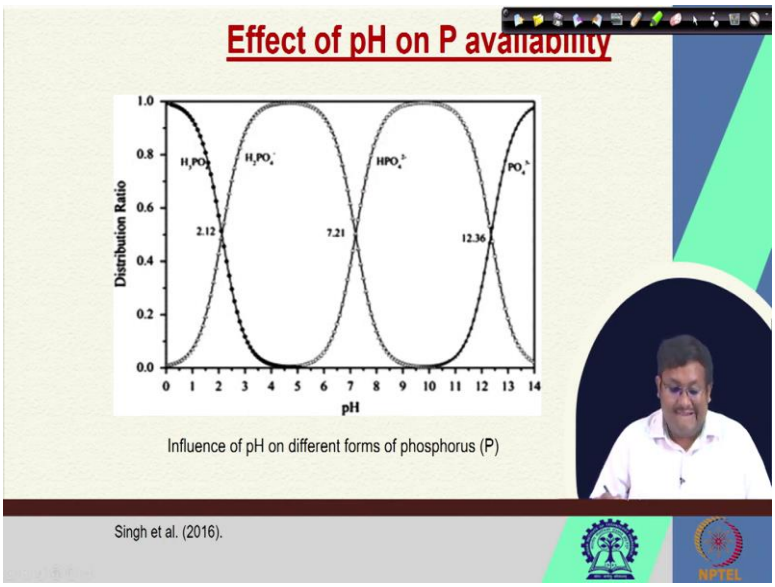

Also, you can see influence of pH in different forms of phosphorus. Here in the x axis, there is a pH, and in the y axis the distribution ratio you can see. At pH around neutral both H2PO4 and HPO4 2 minus are present in equilibrium. However, when we move towards higher pH in an alkaline condition, H2PO4 2 minus predominance and in the acidic condition H2PO4 minus predominates. So, the distribution of these available ions also is governed by the pH of the soil system.

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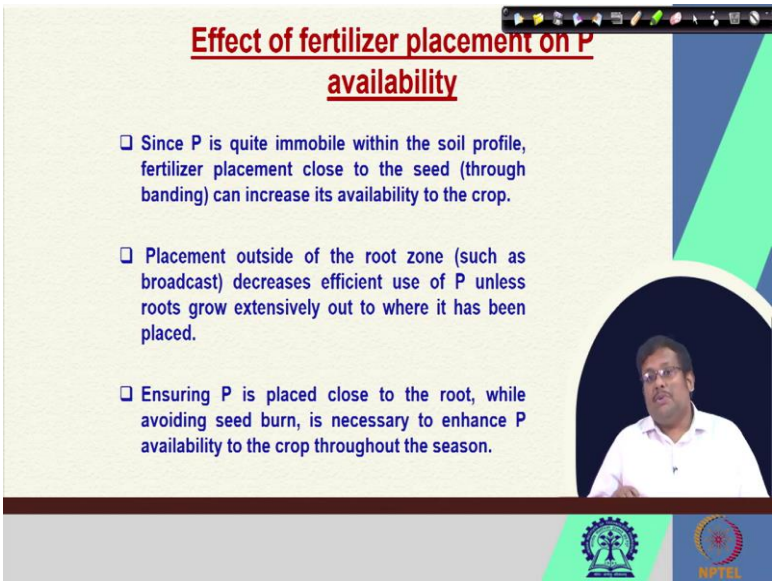

Now, what is the effect of fertilizer placement on phosphorus availability? Since phosphorus is quite immobile within the soil profile, fertilizer placement close to the seed that is through banding can increase its availability to the crop. So, instead of broadcasting the phosphatic

fertilizer, if we place the phosphatic fertilizer in a band around the close to the seed that can increase the availability of phosphorus to the crop.

Otherwise, if we apply through broadcasting that will enhance the phosphorus fixation, and most of the phosphorus will be unavailable to the plant. Placement outside of the root zone such as broadcast decreases efficient use of phosphorus unless root grow extensively out to where it has been placed.

So, in most of the cases, we generally do not recommend broadcasting of phosphatic fertilizer to prevent its loss by precipitation in the form of either calcium phosphate, or iron, or aluminium phosphate. Ensuring phosphorus is placed close to the root while avoiding seed burn is also necessary to enhance phosphorus availability to the crop throughout the season. So, we also should ensure that phosphorus is not creating the seed burn. So that phosphorus placement can be negatively impact the phosphorus availability

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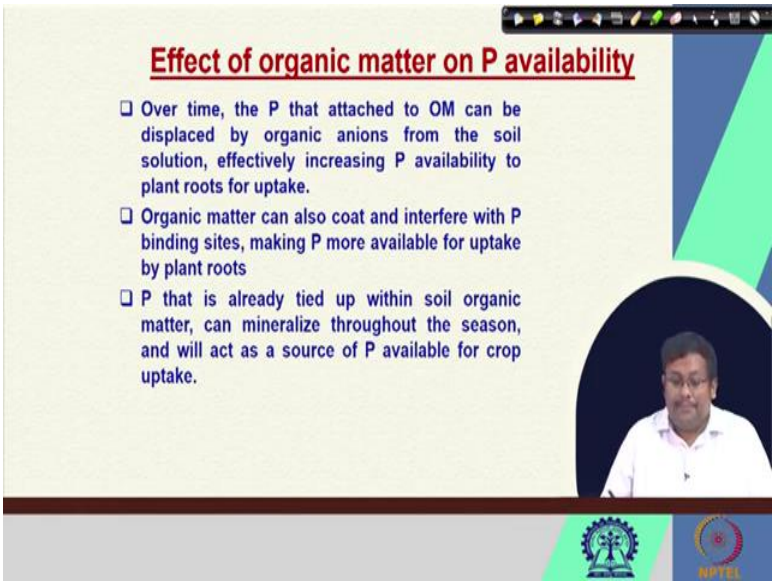

What is the effect of organic matter on phosphorus availability? Over the time the phosphorus that attach to the organic matter can be displaced by organic anions from the soil solution, effectively increasing phosphorus availability to the plant fruits for uptake. So, whatever phosphate or phosphorus ions which are attached to the organic matter, when they are displaced by competing organic anions they come to the soil solution, and becomes available for the plant to uptake.

Secondly, organic matter can also coat and interfere with the phosphorus binding site, making phosphorous more available for uptake by plant roots. So, that is why when we apply the

organic matter that can coat, that can create a coat around the adsorption site and that can interfere with the absorption of phosphorus and ultimately increases their availability.

Phosphorus that is already tied up within the, within soil organic matter can mineralize throughout this season, and will act as a source of phosphorus available for crop uptake. So, phosphorus which is present in organic form, that is organic form of phosphorus can mineralize throughout the season and they can produce the phosphorus which, they can produce the inorganic phosphorus for crop uptake.

So, this is how organic matter can positively influence the phosphorus availability. So, the two major factors that influence the phosphorus availability to the crop, are pH as well as the organic matter presence, you remember that the pH should be near to neutral to enhance the phosphorus availability by reducing the phosphorus fixation, at the same time there should be high amount of organic matter that can displace the bond phosphorus ions and also they can prevent farther binding phosphorus by creating an interfering layer, and also increase the phosphate ion concentration in the salt solution by mineralization of organic forms of phosphorus.

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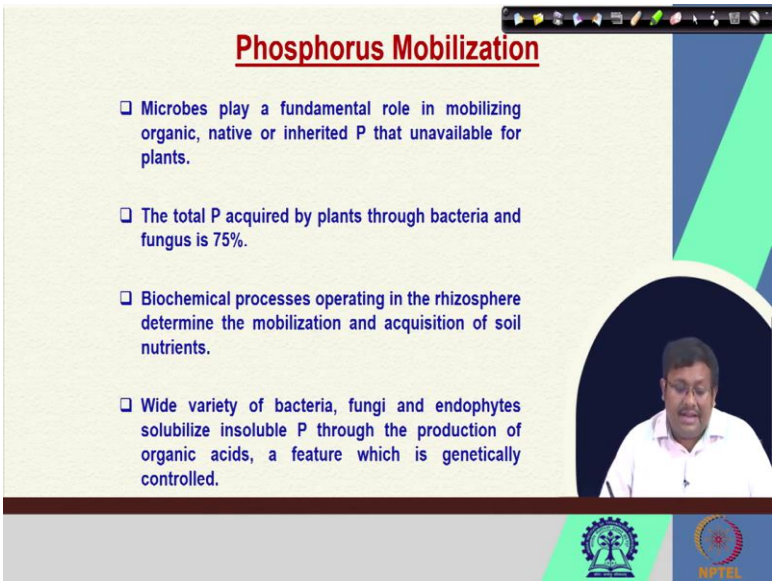

Phosphorus mobilisation, microbes play a fundamental role in mobilizing the organic, native or inherited phosphorus that unavailable for plants. The total phosphorus acquired by plant through bacteria and fungus is about 75 percent, biochemical process operating in the rhizosphere determined the mobilization and acquisition of soil nutrient, there are many biochemical processes which are going on in the rhizosphere which are governed by this microorganism that also determines the acquisition of soil nutrients by the plant root.

Wide variety of bacteria, fungi, and endophytes solubilize insoluble phosphorus through the production of organic acids, a feature which is genetically controlled. So, this phosphorus mobilization is also governed by these different types of microbes and other biochemical process.

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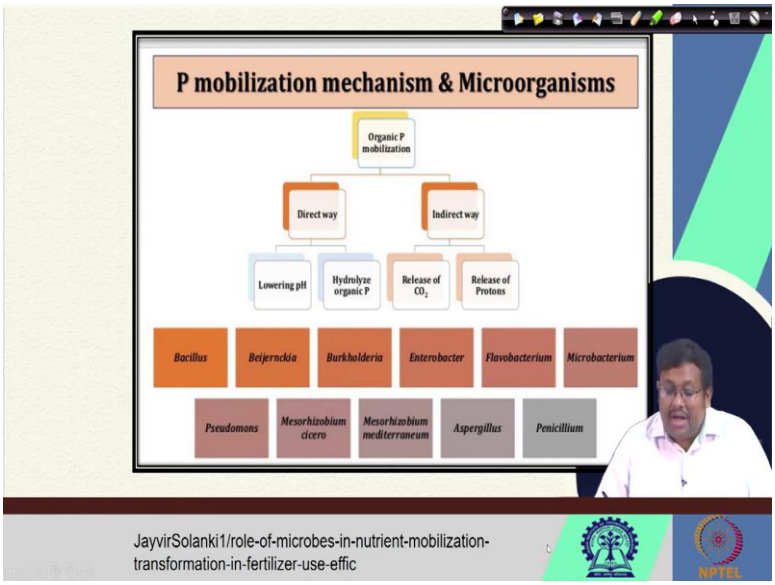

So, if you see the phosphorus mobilization mechanism and microorganisms, we can see organic phosphorus mobilization can be achieved by direct way, or indirect way. In the direct way, we can, it can be achieved by lowering pH, and also hydrolysing the organic forms of phosphorus. And in indirectly, that can be achieved by release of carbon dioxide, and release of protons. So, these are some of the microorganism which take part in phosphorus mobilization in the soil, and this is how phosphorus mobilize in the soil, and mediate which is, mediated by different microbes which are present in the soil.

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So, guys, we have discussed some of the important concepts of phosphorus availability, we have seen how phosphorus is move generally, how phosphorus moves from soil to different other phases, they can be either adsorbed, or they can precipitate. And how the different factors can control the phosphorus availability in the soil we have discussed. And how the phosphorus can be lost from the soil, we have also discussed through different types of leaching, surface runoff and subsurface runoff.

These are some of the references which might be helpful for you to consult, to get a more comprehensive idea about this phosphorus mobilization. We are going to wrap up this lecture here, and we will start from here in our next lecture, and we are going to discuss more about other, more about phosphorus and potassium. Thank you very much.