Soil Fertility and Fertilizers
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Week 5
Lecture 22
Soil micronutrients and their role in plant nutrition (Contd.)

Welcome friends to this lecture number 22 of NPTEL on online certification course of soil fertility and fertilizers and currently we are at week 5.

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And in this week we are talking about soil micronutrients and their role in plant nutrition. So, in our previous lecture, we have seen what are the important micronutrients and why we call them micronutrients we have described, we have discussed.

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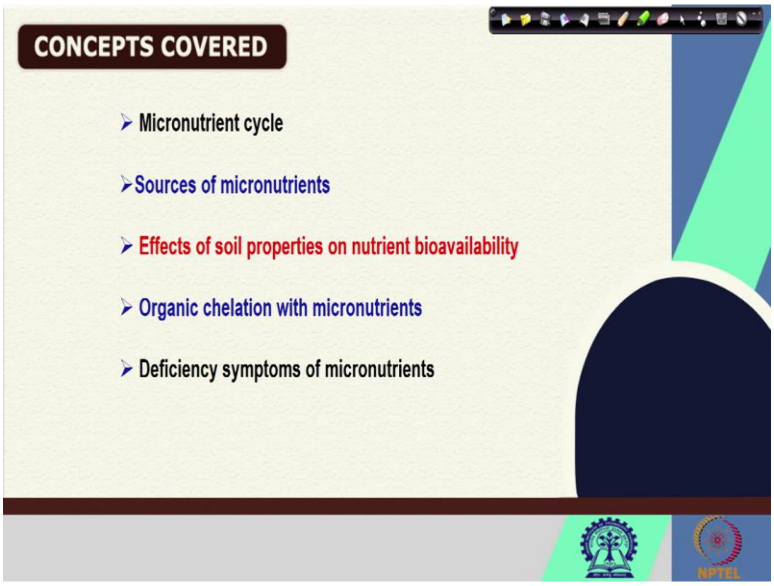

Now, in this lecture we are going to discuss this following concept first of all, we are going to talk about the micronutrient cycle. And then, we are going to talk about different types of sources of micronutrients. Then, we are going to talk about effects of soil properties on nutrient bioavailability specifically, micronutrients, apart from that organic chelation with micronutrients and apart from that deficiency symptoms of some micronutrients. So, we are going to see, what are the deficiency symptoms visually in this in this lecture.

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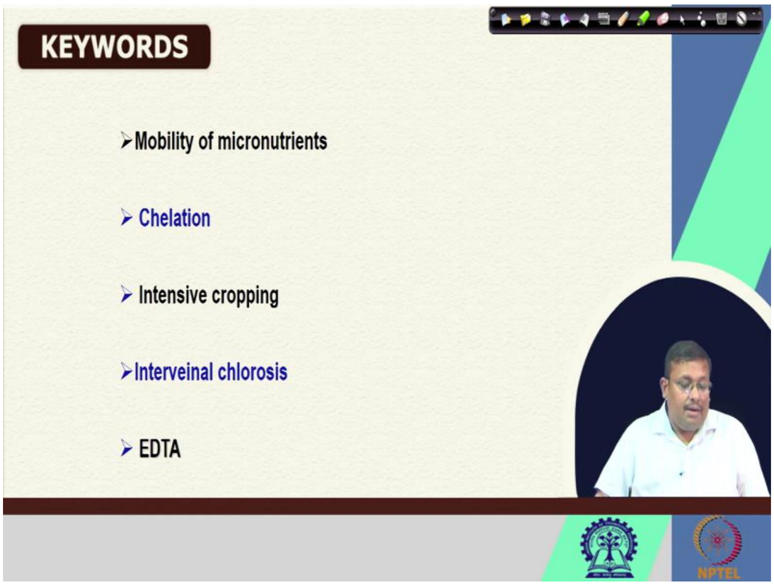

So, these are the key words for this lecture, we are going to talk about mobility of micronutrients then chelation, intensive cropping, intervenial chlorosis and EDTA.

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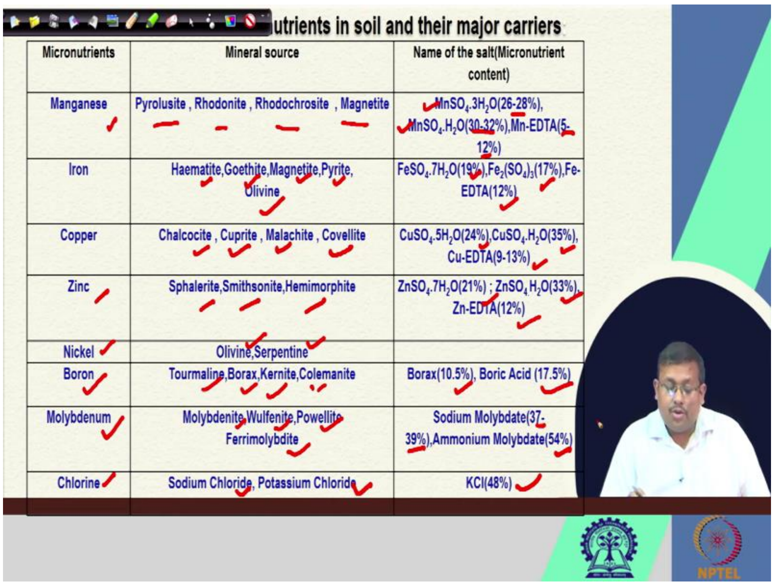

Micronutrients	Mineral source	Name of the salt(Micronutrient content)
Manganese	Pyrolusite , Rhodonite , Rhodochrosite , Magnetite	$MnSO_4.3H_2O$(26-28%), $MnSO_4.H_2O$(30-32%),Mn-EDTA(5-12%)
Iron	Haematite,Goethite,Magnetite,Pyrite, Olivine	$FeSO_4.7H_2O$(19%),$Fe_2(SO_4)_3$(17%),Fe-EDTA(12%)
Copper	Chalcocite , Cuprite , Malachite , Covellite	$CuSO_4.5H_2O$(24%),$CuSO_4.H_2O$(35%), Cu-EDTA(9-13%)
Zinc	Sphalerite,Smithsonite,Hemimorphite	$ZnSO_4.7H_2O$(21%) ; $ZnSO_4.H_2O$(33%), Zn-EDTA(12%)
Nickel	Olivine,Serpentine	
Boron	Tourmaline,Borax,Kernite,Colemanite	Borax(10.5%), Boric Acid (17.5%)
Molybdenum	Molybdenite,Wulfenite,Powellite Ferrimolybdite	Sodium Molybdate(37-39%),Ammonium Molybdate(54%)
Chlorine	Sodium Chloride, Potassium Chloride	KCl(48%)

Now, if you see the sources of micronutrients in the soil, you can see here the, in this table these are given. So, if we also can see their major carriers. So, if we talk about manganese, manganese, the major mineral sources are Pyrolusite, then Rhodonite, then Rhodochrosite and magnetite.

So, these are the major manganese source and the name of the salt which contains this micronutrient are given also site manganese sulfate and then Manganese Sulphate monohydrate then this is try hydrate, then manganese EDTA, EDTA is a chelating agent ethylenediaminetetraacetic acid and also the manganese content is also given in the parenthesis.

So, in manganese sulfate trihydrate we can see 26 to 28 percent of manganese whereas, in this monohydrate case we can see 30 to 32 percent of manganese in case of manganese EDTA it contains five to 12 percent of manganese.

Now, in case of iron the major mineral sources are haematite, goethite, magnetite, pyrite and olivein and these are some of the formulas as well as the nutrient content. So, we can see that ferrous sulphate, heptahydrate contain 19 percent iron and then ferric sulphate contain 17 percent iron and Fe-EDTA contain 12 percent of iron.

In case of copper, the major sources are Chalcocite, Cuprite, Malachite and Covellite. Whereas, these are the major salts, copper sulphate pentahydrate we can see 24 percent of copper copper sulphate monohydrate 35 percent of copper and copper EDTA 9 to 13 percent of copper.

In case of zinc, the major sources are Sphalerits, Smithsorites and Hemimorphite and it is zinc sulphate heptahydrate contained 21 percent of zinc whereas, zinc sulphate monohydrate content 33 percent of zinc and zinc EDTA contains 12 percent of zinc.

In case of nickel, the major sources are Olivine and Serpentine and in case of boron the major sources are Tourmaline, borax, Karnites and Colamanite. And you can see the sources are there also like borax, which is contained 10.5 percent of boron and boric acid which contains 17.5 percent of boron.

In case of molybdenum, the major sources are Molybdenite, Wulfenite, then Powellite and Ferrimolybdite and the major sources are also given salts are also given like sodium molybdate which contain 37 to 39 percent of molybdenum and ammonium molybdate which contain 54 percent of molybdenum and also finally chlorine like the major general sources are sodium chloride and potassium chloride. Whereas in case of potassium chloride it contains 48 percent of chlorine. So, these are the micronutrients sources mineral sources and name of the salts which supply this particular nutrient. Now, let me just bring it here.

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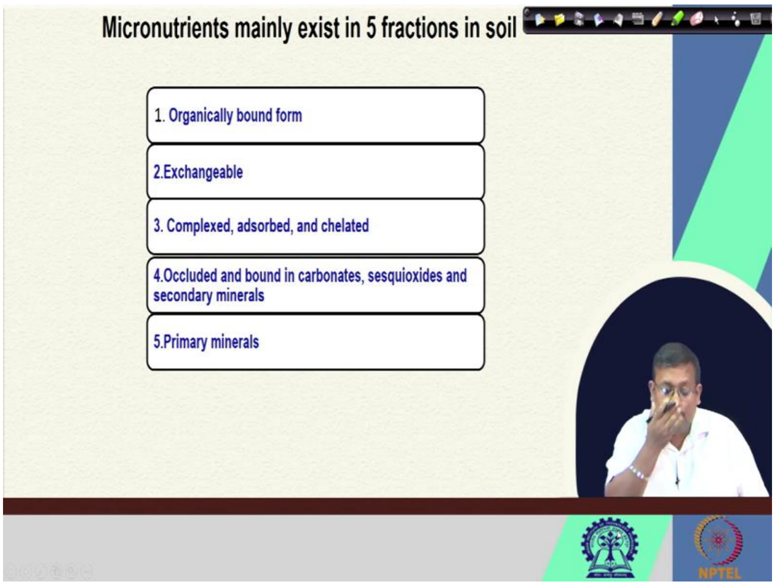

So, let us move ahead and see, what are the fractions in the soil? Where we can see the presence of micronutrients. So, there are primarily 5 different factions in soil where we can see the existence of micronutrients, first of all, in the organically bound form, second is exchangeable form, third one is complex adsorbed or chelated form.

Fourth one is occluded and bound in carbonates, sesquioxides and secondary minerals. Sesquioxides are basically oxides of iron and aluminium and finally, the fifth fraction is primary mineral. So, we can see that all these 5 different fractions can, can contain micronutrients in soil.

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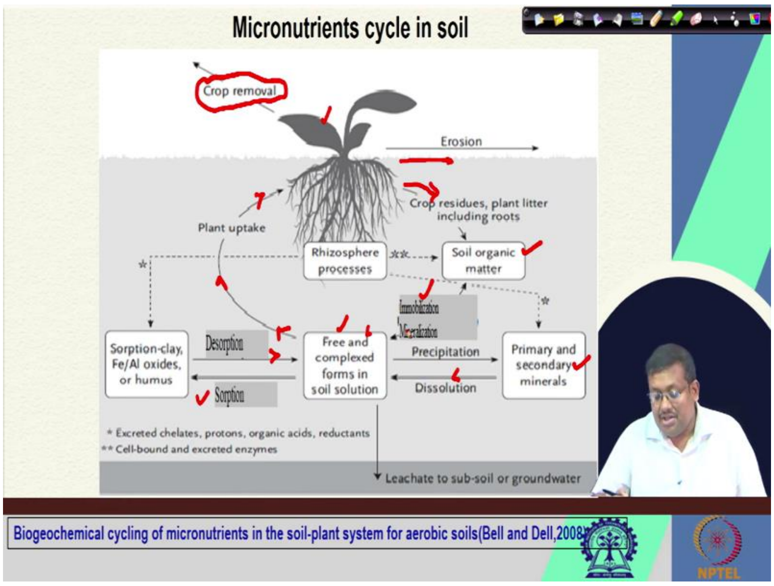

Now, if you see the micronutrient cycle in the soil in general, this is a biogeochemical cyclling of micronutrients in the soil-plant system for aerobic soil, so, we can have an idea. So, if there is a crop, when the crop we are harvesting, the micronutrients are depleting as a result of crop removal. Also, the nutrients get eroded away from the soil and also this plant the plant basically takes up these micronutrients in free and complex form in soil solution through their roots and due to different types of rhizospheric processes also, soil organic matter that in the rhizospheric process influences soil organic matter.

Now, soil organic matter comes from crop residues plant litter including roots. So, these decomposition will create the soil organic matter and these and also different types of mineralization and immobilization, can produce or can move can help in enriching the soil solution with the specific iron.

So, when the soil organic matter decomposes and mineralization process occurs, the micronutrients comes to the soil solution from where the plant uptakes this nutrients, the opposite process is mineralization or this opposite process of mineralization is immobilization, where these free ions are incorporated in organic forms.

So, that is called the immobilization process. Apart from that, there is a precipitation of these free and complex forms of ions from soil solution to the primary and secondary minerals and the opposite process is dissolution where these primary and secondary minerals supply these ions into the soil solution and enriching the soil solution for the further plant uptake.

Sometime these ions from the soil solution gets solved on clay and iron oxides iron aluminum oxides are humus complex and the opposite process is desorption from where these micronutrients, where again come, micronutrients come back again from this salt from to these free and complex form in the soil solution. So, this desorption process. So, this is how these micronutrients move in the biogeochemical cycle in the soil plant system in case of aerobic soil condition.

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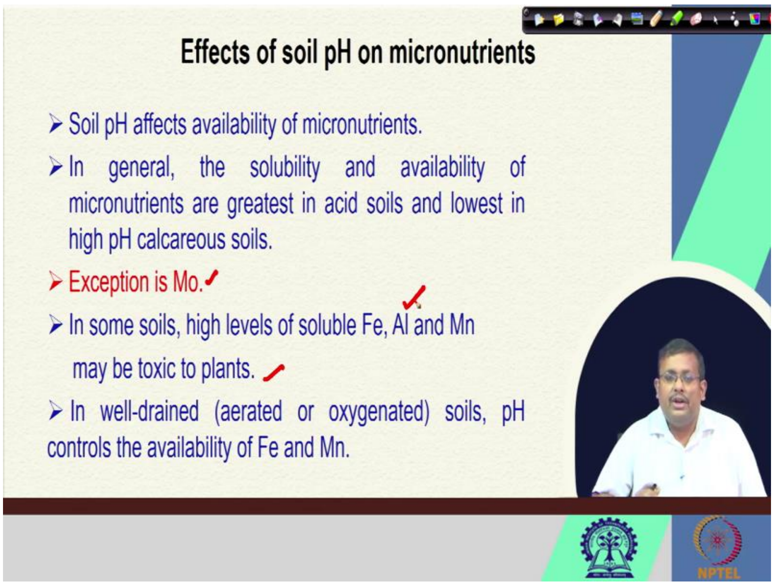

Now, if we go ahead and see the effects of soil pH on micronutrients. So, the soil pH affects availability of micronutrients. In general, the solubility and availability of micronutrients are greatest in acid soils and lowest in high pH calcareous soils. So, of course, when there is a high pH in the soil, that is more or less calcaneus because that contains high amount of calcium. So, in this condition these micronutrients are more or less unavailable, only one exception is molybdenum which is available in that high alkaline soil.

Now, in some soil high levels of soluble iron, aluminium and manganese may be toxic to the plants um all of these aluminium toxicity is very much important.

So, in case of highly acidic soil the aluminium can be present in toxic concentration to severely affect the root growth. So, that is why high concentration of aluminium in the acidic soil is not at all suitable for plant growth in well-drained soil, which is either edited or oxygenated pH controls the availability of iron and manganese. So, these are some of the important consideration when we talk about the effects of soil pH on availability of the micronutrients.

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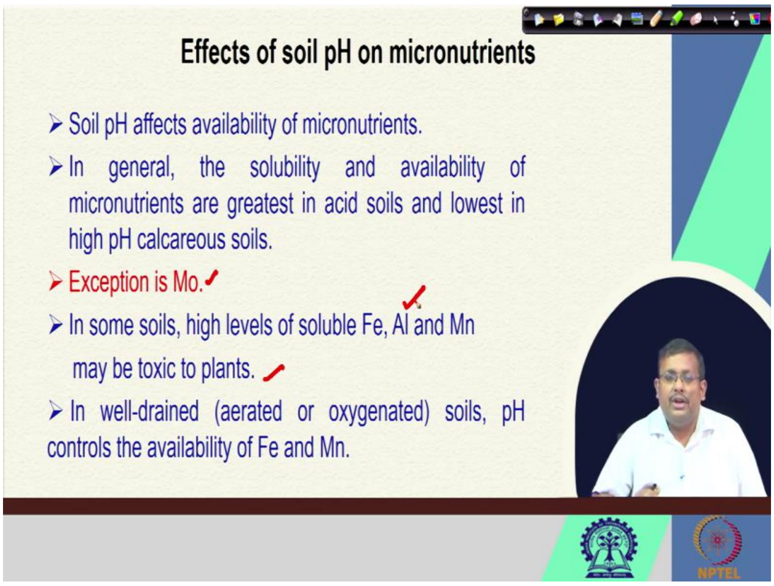

Now, this picture shows how soil pH affects the availability of different plant nutrient you can see here the nitrogen is more or less available, when the soil pH is very slightly acidic to very slightly alkaline.

So, these nitrogen, phosphorus, potassium, sulphur they are specifically nitrogen and phosphorus are available in in slightly acidic to slightly alkaline condition. Whereas, in case of potassium and sulphur they are more available their availability increases from slightly acidic to slightly very slightly acidic to alkaline soil in case of calcium, their availability increases their availability is high both for both calcium and magnesium in this, in this zone where from very slightly acidic to very slightly alkaline.

Whereas magnesium availability extends more, in case of iron manganese and boron their availability is more in case of acidic condition, we can see in case of copper and zinc also the same is applicable however, in case of molybdenum we can see their availability increases in strongly alkaline soil.

So, for optimum pH availability of all the essential plant nutrients we can maintain a soil pH at 6.5 or above by liming but soil pH should be kept below 7. So, you can see the soil pH should be kept below 7. So, that most of the micronutrients or other nutrients can be available.

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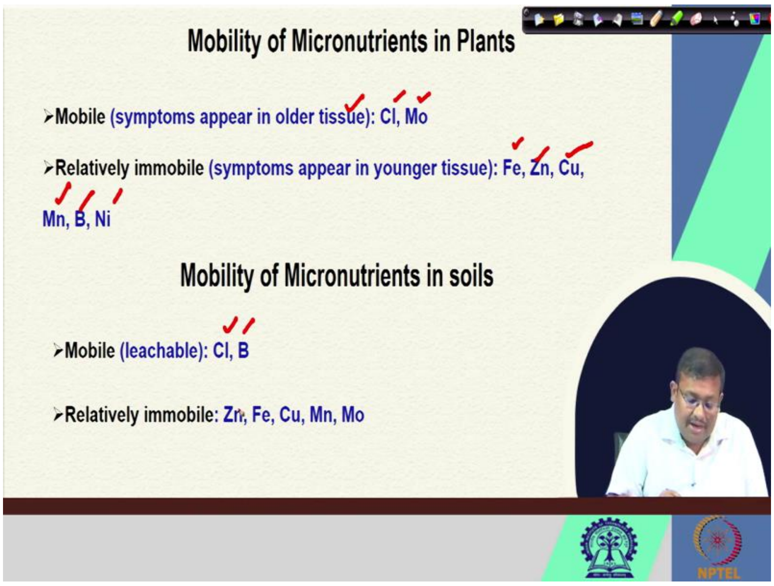

So, what about the mobility of micronutrients in plants and in soil. So, in plant the mobile micronutrients are chlorine and molybdenum because and also because the their symptoms deficiency symptoms appear in older tissues just like nitrogen and on the other hand, iron zinc, copper, manganese, boron and nickel are relatively immobile and their symptoms deficiency symptoms appear in younger tissue as far as the mobility in soil is concerned, so, this chlorine and boron are mobile so, they can be easily leached away from the soil and relatively immobile are zinc, iron, copper, manganese and molybdenum. So, these are the relatively immobile nutrients in the within in the soil.

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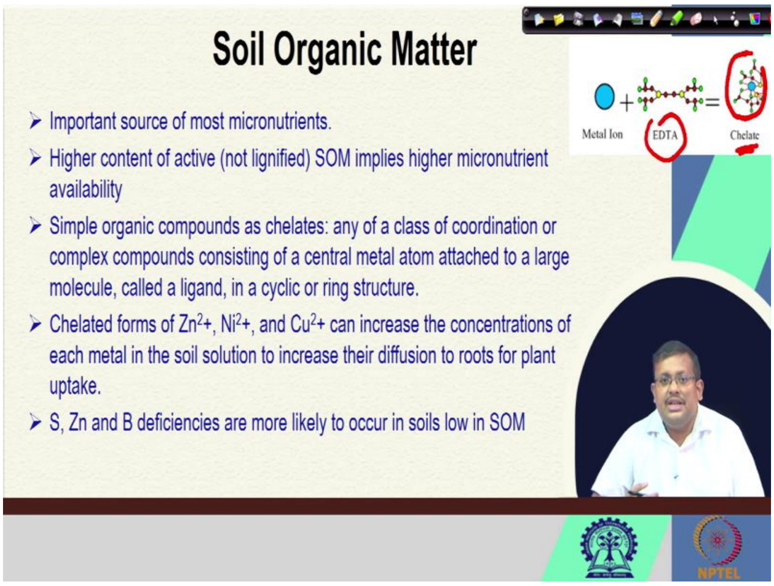

So, another very important factor that affects the mobility or availability of the micronutrients is soil organic matter, because it is an important source of most of the micronutrients and higher content of active soil organic matter implies higher micronutrient availability, because it is soil organic matter is known as the storehouse of nutrients. So, more organic matter means more micronutrient availability the plant. Now, simple organic compounds is chelates can also improve the availability of the micronutrients because the, they can improve the availability of the micronutrients by chelating those metal cations.

Now, what is chelating? Chelates is a any class of coordination or complex compound consisting of a central metal atom attached to a large molecule and in a cyclic or ring structure. So, here you can see there is a metal ion and in this metal ion is chelated by these this chelating agent that is called EDTA ethylene diamine tetra acetic acid to form a ring like structure and this whole structure is known as Chelated.

So, you can see there is particular metal ion is surrounded in a ring like structure by these EDTA molecules. So, that is why it is called a chelating agent or ligand and ultimately it produces this chelate. So, chelated forms of zinc nickel and copper can increase the concentration of each metal in the soil solution to increase their diffusion to root for plant uptake. And then sulfur, zinc and boron deficiencies are also more likely to occur in soils, low in soil organic matter because the soil organic matter contains these different micronutrients. So, when the soils are deficient in soil organic matter, then we can assume that sulphur, zinc and boron deficiency can occur.

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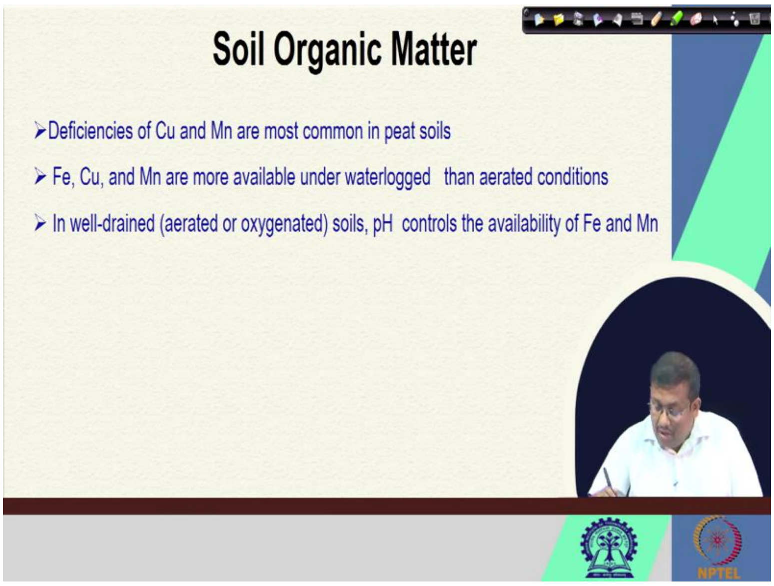

So, also deficiencies of copper and manganese are most common in peat soil just the opposite thing we can see in case of high organic matter soil because these copper and manganese are very much, they have high affinity to attach to the organic matter. So, that is why this copper and manganese can form is very stable complex with organic matter and as a result of that, their availability is reduced.

So, we can see the deficiency of in copper and manganese in peat soil which is high in which are high in organic matter. Then iron copper and manganese are more available under water log than aerated condition and in well-drained soil pH controls the availability of iron and manganese we have already seen that.

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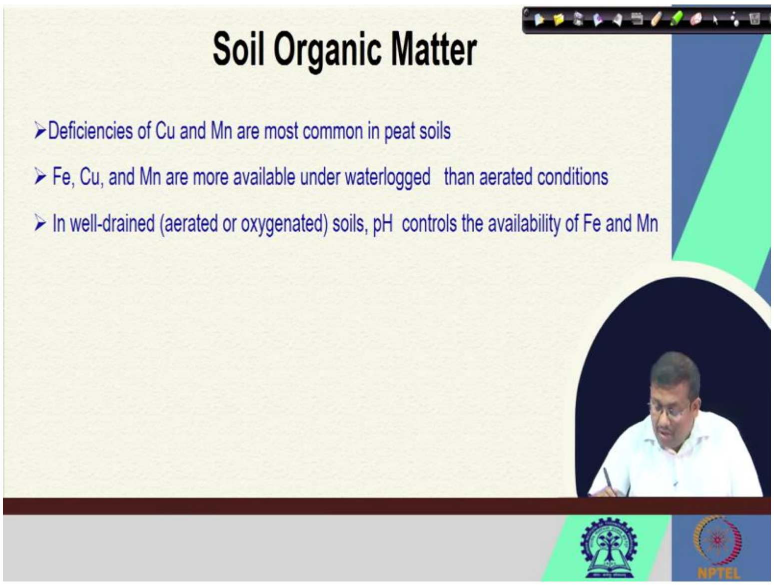

Now, the organic chelation with micronutrients. So, natural organic chelates in soil are product of microbial activity and degradation of soil organic matter plant residues we know that whatever natural organic chelates are present in the soil.

Now, mainly natural organic chelates have not been yet identified. However, compounds such as citrate and oxalic acid formed during the decomposition have chelating properties. Artificial ciliates are widely used in micronutrient fertilizer application to increase the micronutrient availability to the plant.

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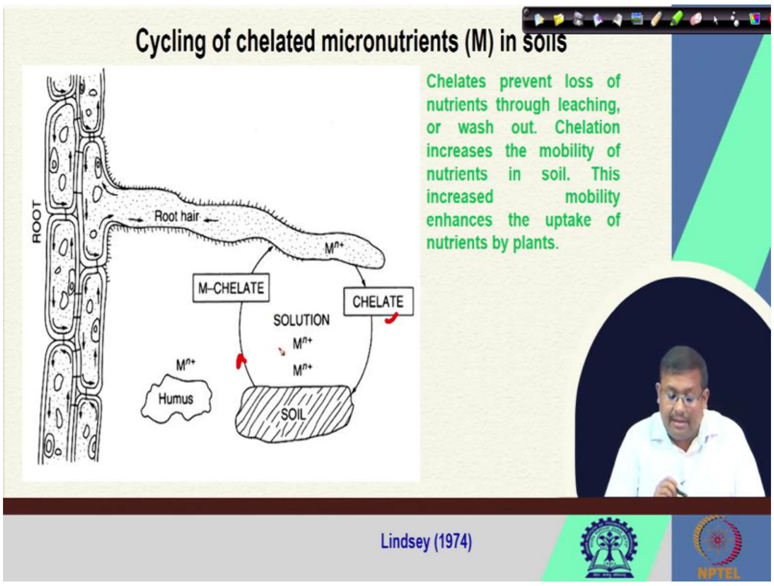

Now, how these chelates improve these micronutrients availability, chelates prevent loss of nutrients through leaching or washing out and chelation increases the mobility of nutrients in the soil at these increased mobility enhance the uptake of the nutrients to the plants.

So, here you can see there is a chelating agent and when it goes to the soils, it gets complex it makes the complex of this metal ions and then this metal ion complex can go to the root surface and then release this metals to be uptaken by the plant. So, the so, basically this increased mobility of the nutrient can be facilitated by the presence of this chelating agent.

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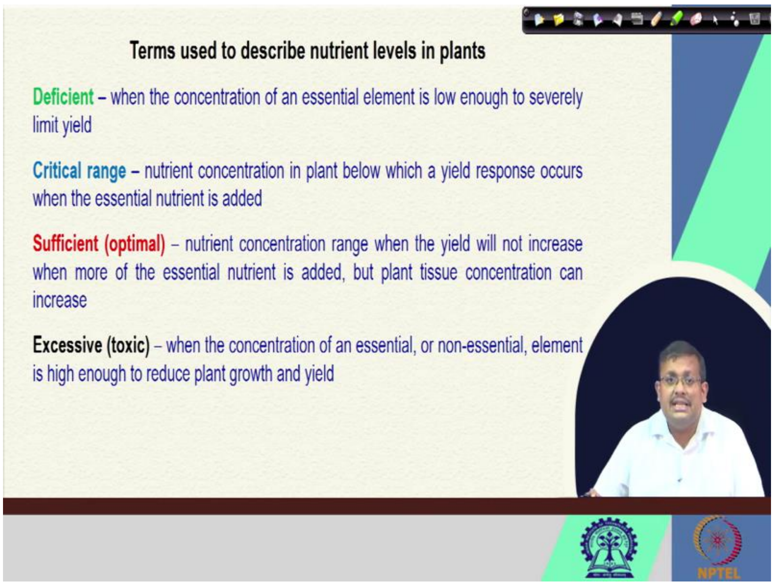

Now, what are the different terms which are used to describe the nutrient levels in plants, first of all is deficient second is critical range third one is sufficient or optimal and fourth one is excessive or toxic.

Now, what is deficient, deficient we call a nutrient condition deficient when the concentration of an essential element is low enough to severely limit the yield. When the diff when the concentration of a particular element produce the severe diff serious symptoms and retarding the growth that is called deficient condition, what is critical range? it is a nutrient concentration in plan below which a yield response occurs when the essential nutrient is added.

So, generally the critical concentration is critical range is a concentration in the plant below which if we add fertilizer of a particular nutrient that will give that will show the yield response to the crop.

The third one is sufficient or optimal nutrient concentration. So, doing the, it is a range. So, when the nutrient concentration range, this nutrient content is concentration range, where the eel does not increase when more of these essential element is added.

So, basically it is led to, so, if we go on applying these nutrient and we see the growth of the plant, when the growth of the plant reaches a plateau that is called a sufficient or optimal nutrient concentration.

So, we cannot see any substantial yield growth or yield increase however plant tissue concentration can increase. The last one is called the excessive a toxic concentration, when the concentration of an essential or non essential element is high enough to reduce plant growth and yield that is called toxic or excessive concentration. So, these are some of the important concepts concepts, which we frequently use for soil fertility and fertilizer application.

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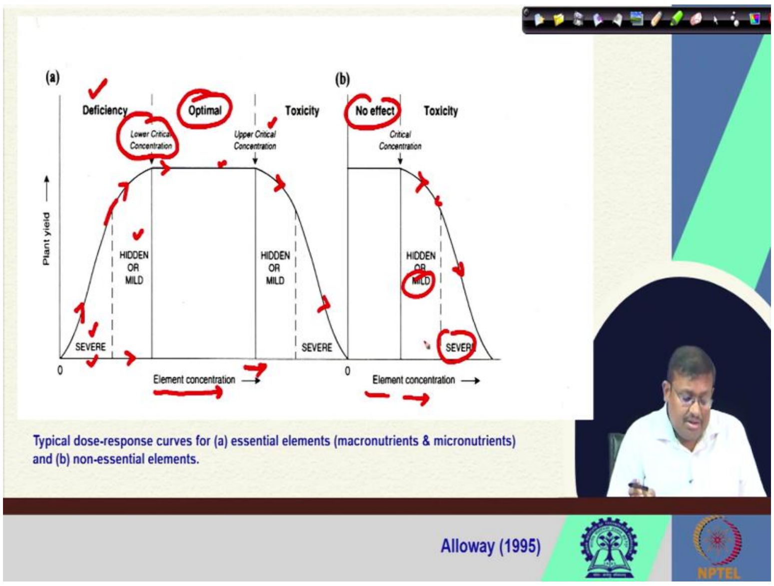

Now, if we see these are, these the typical those response curve for this is an essential element curve and this is the, this is for non essential elements. So, we can see that when the elemental concentration of of a specific essential element we go on increasing. So, at initial stage we can see this high increase of plant, how high increase of plant yield. So, the here in this zone you can see there is a severe deficiency.

So, the slope of increase of implant deal with increasing elemental concentration is very high. And then as we go on increasing the concentration, you can see the slope is decreasing and ultimately, it reaches a point from where it goes in a plateau.

So, here this point is known as the lower critical concentration. So, below this lower critical concentration, there is a deficiency zone, in the deficiency zone we can see severe deficiency or hidden or mild deficiency and up to that critical level, this is an upper critical level concentration up to which we can see there is no change in plant yield with the increasing elemental concentration.

So, this is the optimal range of plant nutrition, plant nutrient content however, when we go on increasing the essential element concentration, a time will come after these upper critical concentration, you will see the, there will be a reduction in plant growth, which is also can be divided into 2 zone that is 1 is mild zone and other is severe zone in the severe zone, the rate of decline is very high as compared to the mild zone.

So, this is how these a group dose response curve for essential elements. However, in case of a non essential element, when you increase the elemental concentration in the in the in the soil, you will see that there is no effect however, there will be a critical critical concentration beyond which you will see there will be a decrease in plant yield.

So, that can be also divided into mild as well as severe decline in plant yield. So, this is how we can see the dose response curves for essential elements and non-essential elements.

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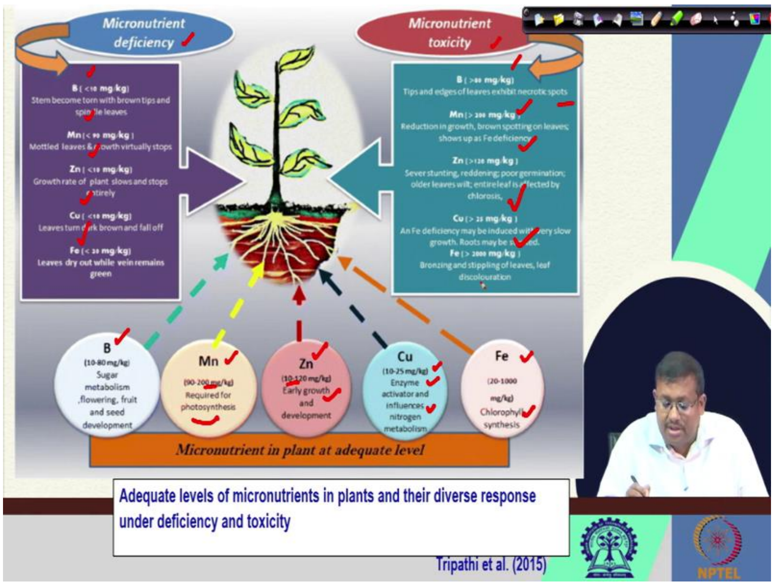

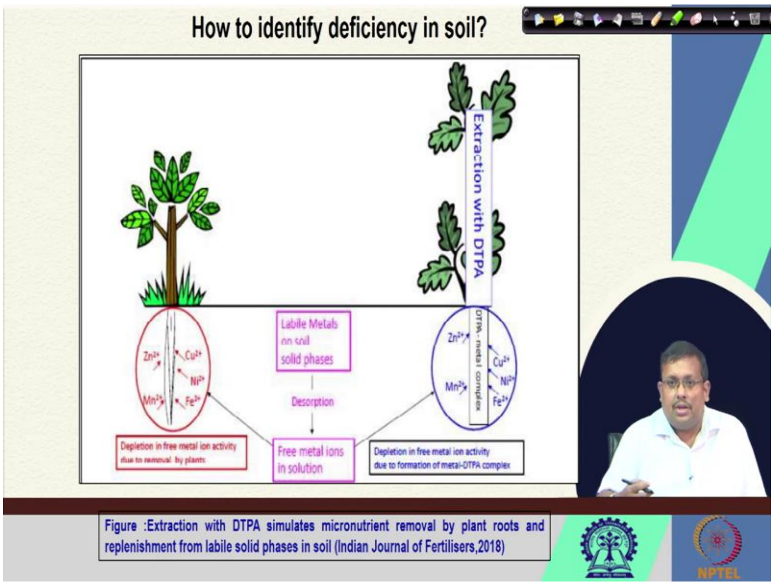

Now, this slide shows the adequate levels of micronutrients in plants and their diverse response under deficiency and toxicity. So, you can see the micronutrient toxicity levels and micronutrient deficiency levels are given here. So, if we can see the the micronutrient in plant adequate level in case of boron that is 10 to 80 ppm, in case of manganese this is 900, 90 to 200 ppm, in case of zinc that is 100 to 120 ppm of course, the stages are given there like sugar metabolisms, stage flowering stage fruit and seed development stage.

Then, manganese in case of manganese the 90 to 200 ppm there is requisite for photosynthesis and then zinc is 100 to 120 in ppm, which is required for early growth and development stage.

Copper 10 to 25 ppm, which is required for enzyme activation, activation and influencing the nitrogen metabolism. Iron is 22,000 ppm for chlorophyll synthesis. So, these are the adequate level within the plant however, when the boron is less than 10 ppm, manganese is less than 90 ppm and then zinc is less than 10 ppm, copper is less than 10 ppm and iron is less than 20 ppm, then we can see the deficiency symptoms like leaves dry out when vein remains green so, it is in case of iron, in case of copper we can see leaves turn dark brown and fall off.

In case of zinc we can see growth rate of plant (sherb) slows ends and stops entirely in case a manganese motal leaves and growth virtually stops and in case of boron we can see (steb) stem become torn with brown tips and, and spindle leaves. In case of micronutrient toxicity, just opposite we can see boron is greater than 80 ppm, manganese 200 ppm greater than 200 ppm, zinc is greater than 120 ppm, copper more than 25 ppm, iron more than 2000 ppm.

So, in case of boron toxicity, we can see tips and ages of leaves exhibit necrotic spot in case of manganese toxicity, we can see reduction in growth, brown spot on leaves, and then and also in case of zinc we can see severe stunting of the crop.

And then retaining poor germination and then wilting of older leaves then chlorosis of the entire leaf. And then in case of copper toxicity, we can see an iron deficiency may be induced with very low growth and roots may be stunted, in case of, in case of copper, in case of iron we can see bruising and stripping of leaves and leaf discoloration. So, these are the optimal range and then micronutrient deficiency and then micronutrient toxicity for the plants.

So, how to identify the deficiency in the soil so, basically extraction with the DTPA, DTPAs and other ciliates. So, we generally extract the micronutrients from the soil through DTPA because DTPA simulates, micronutrient removal by plant fruit and replenishment from level soil phases in the soil.

So, we know that the plant roots absorb these nutrients from these free metals from the soil solution, which shows the depletion in the free metals and activity due to removal by the plant and these and these, so, the free metal ions in the solution can also be chelated and taken away by extraction by with the DTPA which also can resemble the depletion in free metal ion activity due to the formation of metal DTPA complex. So, that resembles the depletion of free metal ion due to removal of the plant. So, that is why we generally use these

DTPA extraction to, do and then after DTPA extraction, we measured them using standard methodology for identifying their concentration in the extracted solution.

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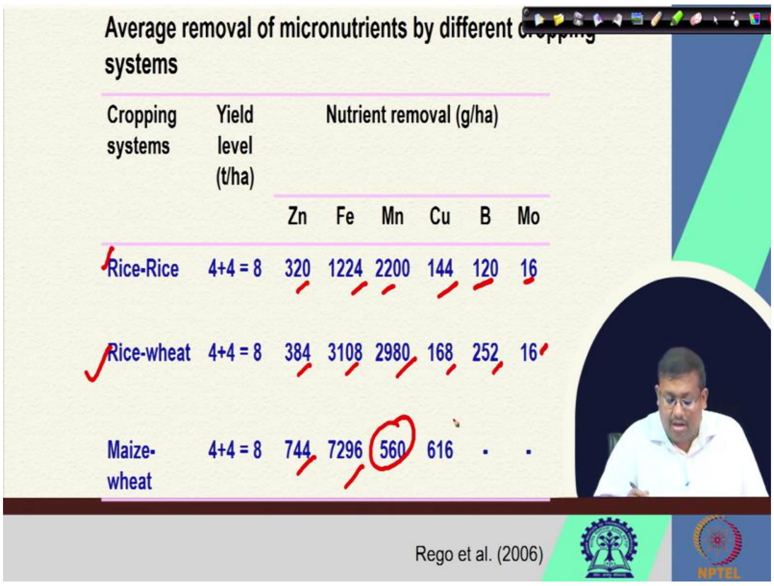

So, if we can see the average removal of micronutrients by different cropping system. So, in case of rice rice cropping system, we can see that this is the removal of zinc, iron, manganese, copper boron molybdenum, in case of rice wheat system of course, we can see even creased nutrient removal micronutrient removal here 384, 3108 and then 2980, 168, 252.

And only in case of molybdenum they are same. In case of Maize-wheat system. Of course, the nutrient removal is more because maize is a heavy feeder crop and except for manganese and and we can see that in case of zinc and iron and also in higher copper removal from the soil in gram per hectare.

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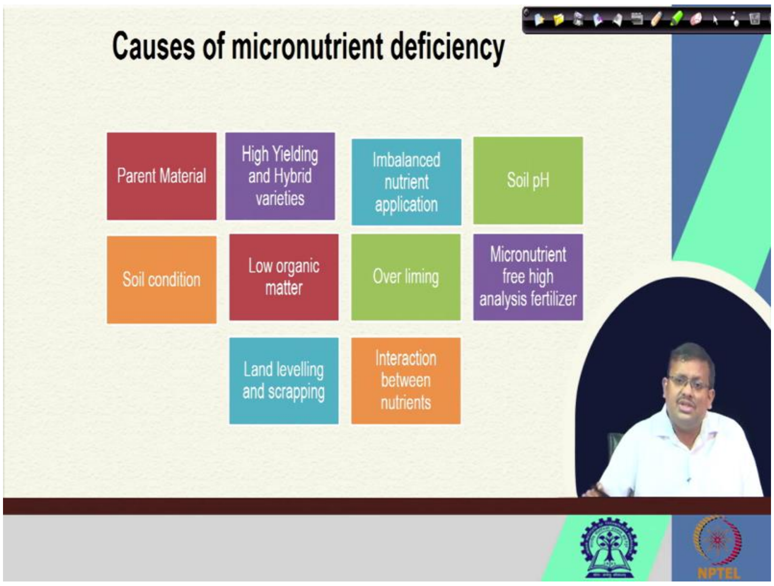

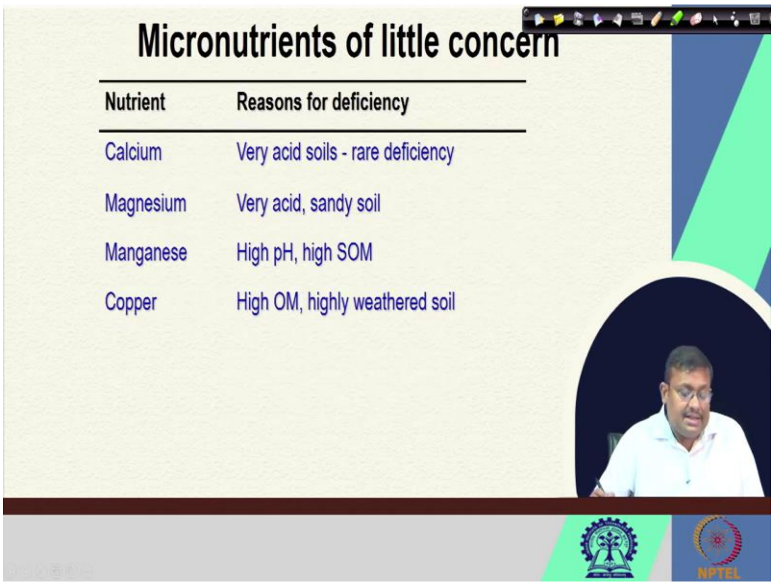

So, what are the causes of micronutrient deficiency there are different types of causes of micronutrient deficiency, one is parent material, then highlighting and hybrid varieties, imbalanced nutrient applications soil pH, soil condition, low organic matter, overlining, micronutrient free high analysis fertilizers high end is fertilizer means, those fertilizer which are containing high amount of more than 30 percent of nutrients, available nutrients and land leveling and scrapping and interaction between nutrients.

So, all these are different causes of micronutrient deficiency, micronutrients of little concern you can see calcium, magnesium, manganese and copper are of little concern because of this reason for example, in case of calcium the deficiency can be seen in very acidic soil which is rare deficiency. Magnesium deficiency can be seen in very acidic and sandy soil. Manganese deficiency can be seen in case of high pH, high soil organic matter soil, and in case of copper deficiency, it can be seen in high organic matter highly weathered soil. So, these are micronutrients of little concern.

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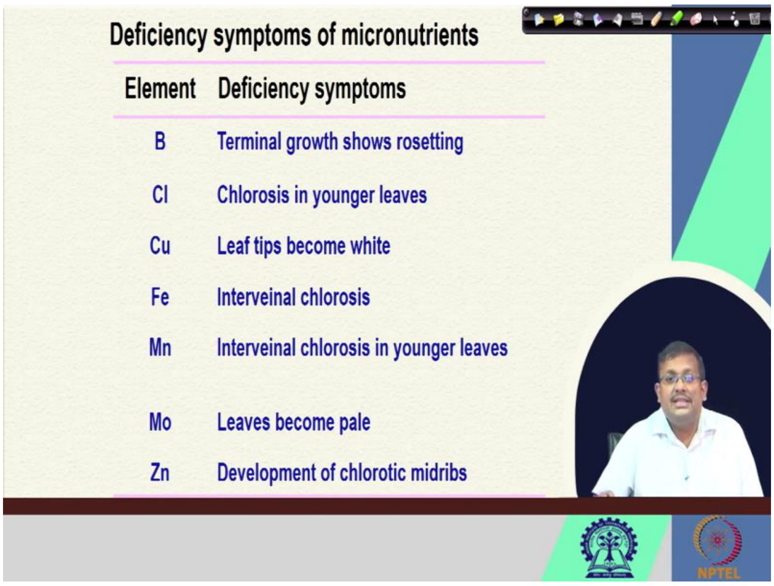

And these are the deficiency symptoms of the micronutrients like in case of boron terminal growth shows and also shows rosetting and then chlorine chlorosis in younger leaves, copper leaf tips become white, Iron interveinal chlorosis, manganese interveinal chlorosis in younger leaves. In case of molybdenum deficiency, we can see Leaf becomes pale and in case of zinc development of chlorotic midribs. So, these are the deficiency symptoms of these micronutrients.

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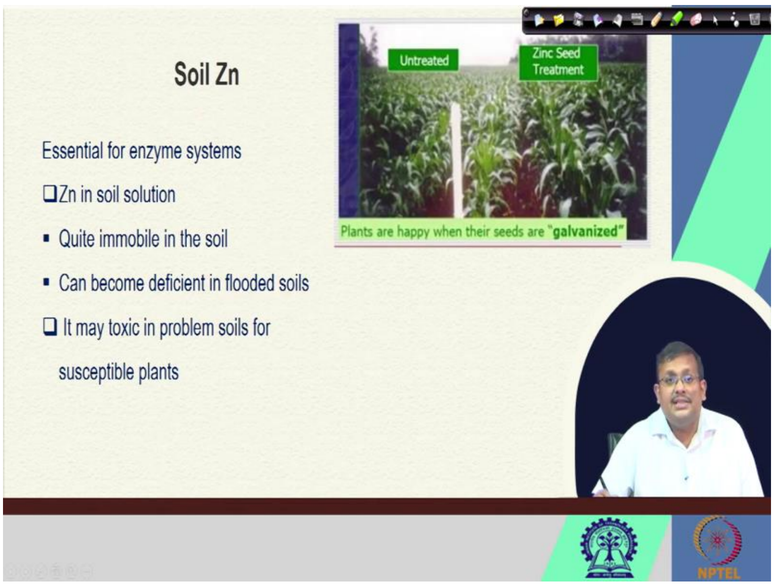

So, if we talk about the soil zinc, the zinc is very much essential for enzyme system and zinc in solution can quite immobile in soil and can become deficient in flooded soil, it may be toxic in in problems soil first susceptible plants. So, you can see 2 conditions where zinc a 1 untreated soil and that is zinc untreated soil and another is zinc treated soil.

So, you can see clearly the difference between these applied and non apply zinc and non-zinc applied plant response.

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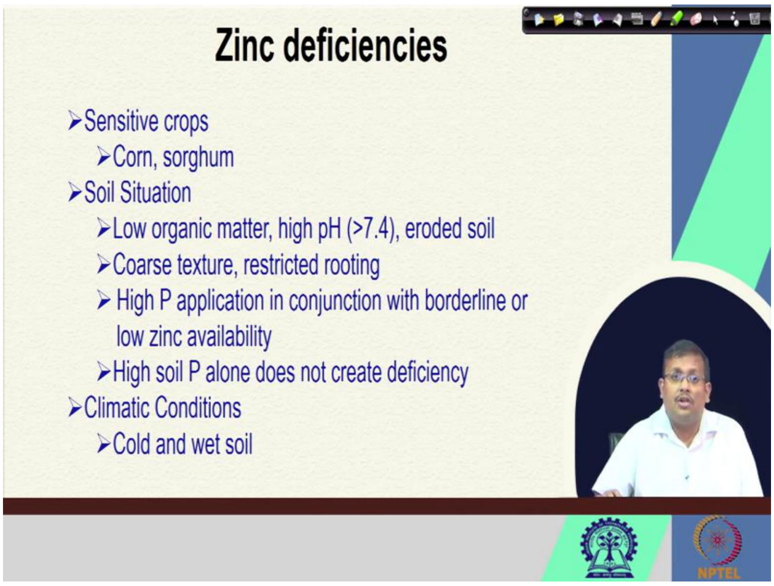

So, if you see these Zinc deficiencies there are several types of sensitive crops like corn, sorghum and there are several soils situation which can enhance the zinc deficiency like low organic matter, high pH, eroded soil, coarse texture, restricted routing high phosphorus application because there is an antagonism between phosphorus and zinc. So, high phosphorus application in conjugation with borderline or losing availability then high soil phosphorus alone remember that high soil phosphorus alone does not create the deficiency, but with borderline or losing availability is another cause and then in case of climatic condition, cold and wet soil is another cause of zinc deficiency.

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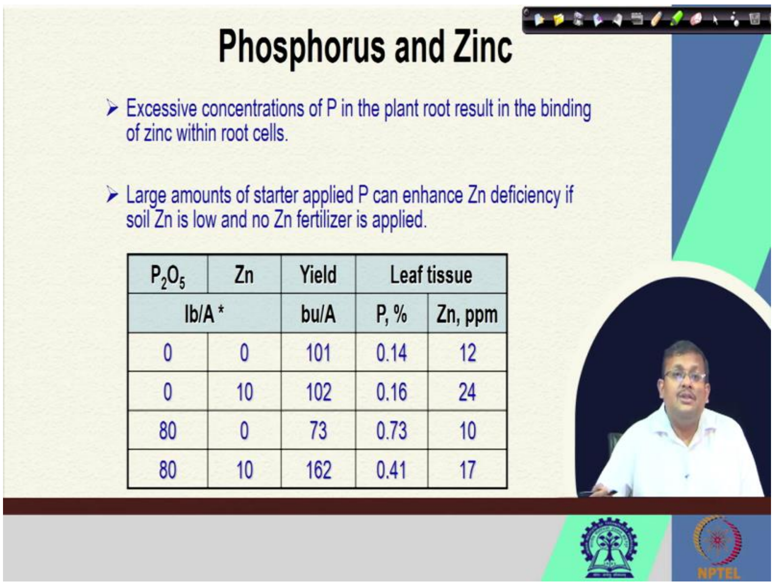

So, if you see the phosphorus and zinc relationship excessive concentration of phosphorus in the plant root results in the binding of zinc within the root cell. So, large amount of started application of phosphorus can enhance zinc deficiency, if soil zinc is low and nosing fertilizer is applied. I have mentioned in the previous slide that more soil phosphorus fertilizer application with borderline zinc condition can aggravate the zinc deficiency.

So, here you can see 0, 0 both of them are same. And here when we are phosphorus pentoxide or petoferrous is 0, we can see higher zinc concentration. So, you can actually you can see the yield is increasing and also you can see here when 80 to 0, 80k pound per acre. P 2 O 5 is given and 0, we can see here and also when we apply this 10 ppm, 10 pound of zinc per acre, we can see these concentrations.

So, we can see here one thing that there is a antagonistic relationship between phosphorus and zinc. So, when the phosphorus is low zinc is high however, when phosphorus concentration in the tissue increases, zinc concentration goes down.

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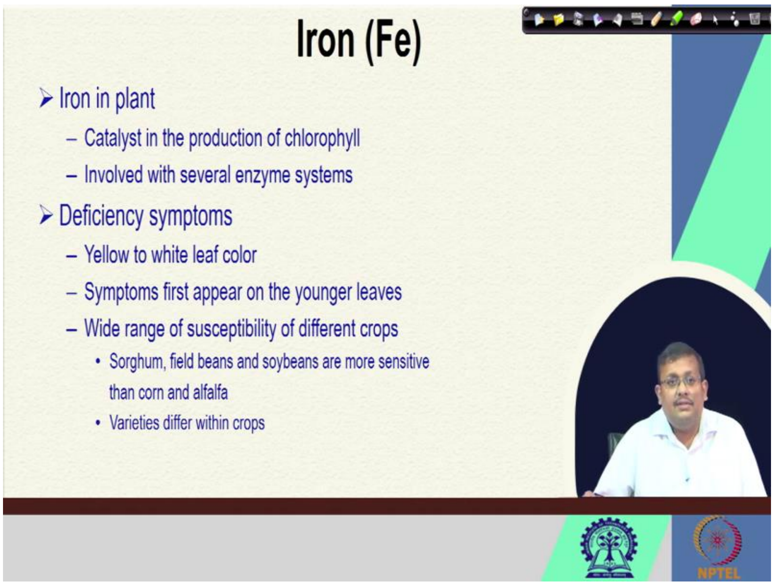

Iron, Iron in plant catalyzes the production of chlorophyll and it is involved with several enzyme systems and the deficiency symptoms of iron can be seen in terms of yellowing to whitening of leaves and then symptoms first appear in the younger leaves and wide range of susceptibility of different crops can be seen as far as the iron deficiency is concerned.

So, sorghum field beans and soybeans are more sensitive than corn and alfa alfa and varieties differ within the crop also in terms of iron deficiency symptoms.

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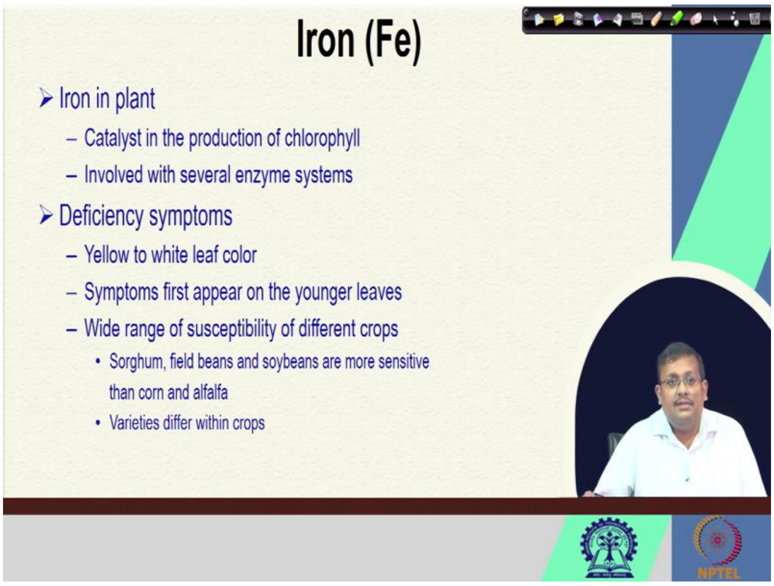

So, guys, let us wrap up this lecture and these are the references for this lecture. I hope you have got some idea about nutrient suffecency and deficiency and we are going to continue these nutrient deficiency symptoms in our coming lecture. And we will discuss what are the deficiency symptoms of different types of micronutrients in different crops. Thank you.