Soil Fertility and Fertilizers
Professor Somsubhra Chakraborty
Agricultural and Food Engineering Department
Indian Institute of Technology, Kharagpur
Lecture 19
Soil Secondary Nutrients and Their Role in Plant Nutrition (Cont.)

Welcome friends to this 19th lecture of NPTEL Online Certification Course of Soil Fertility and Fertilizers. In this week we are discussing about Soil Secondary Nutrients and Their Role in Plant Nutrition. And in the previous three lectures we have discussed about two important secondary nutrients calcium and sulphur.

We have discussed their cycles, also we have discussed their sources, their deficiency symptoms and how to correct those deficiency symptoms using different types of fertilizers; what are the sources of those elements and also we have discussed what are the factors which affect their availability to the plant.

We have seen that due to the deficiency of those fertilizers, severe deficiency can occur in the plant. So today we are going to discuss or start about the plant metabolism. How it is dependent on magnesium, which is another important secondary nutrient. And how magnesium controls the plant growth? What is the magnesium cycle and what are the sources of magnesium? We are going to discuss.

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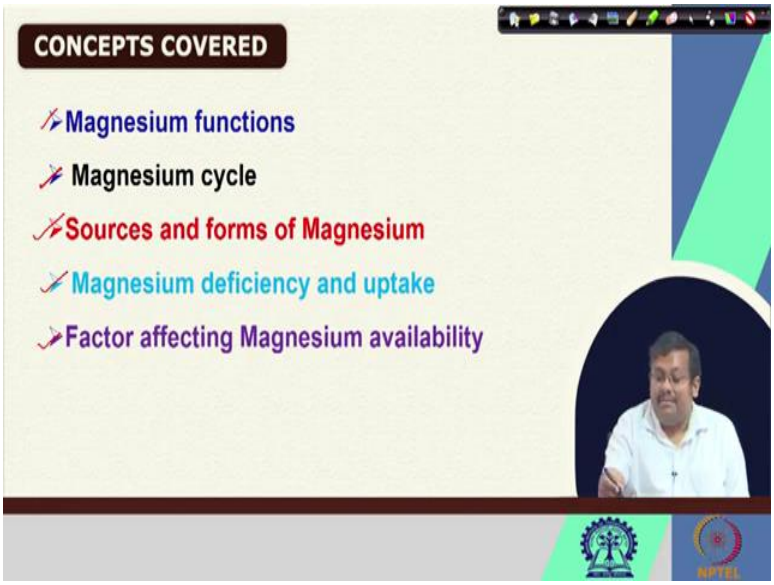

So let us start. So these are the concepts which we are going to cover. First of all, we are going to cover the functions of magnesium. We want to also discuss the magnesium cycle. And also next we want to discuss the sources and forms of magnesium. Then we are going to discuss the magnesium deficiency and uptake and finally, we are going to discuss the factors which affect the magnesium availability.

So these are some of the concepts which we are going to cover. Magnesium functions as you know are very much important. Magnesium cycle we want to discuss because to identify or understand how magnesium is, generally occurs in the soil and how it is present in the soil in different forms and also what are the equilibrium between these forms.

And also sources and forms of magnesium we are going to discuss. And then magnesium deficiency in uptake we are going to discuss. And finally those factors which you should remember are considered before designing the corrective measures of magnesium deficiency. That means those factors which affect the magnesium availability we are also going to discuss.

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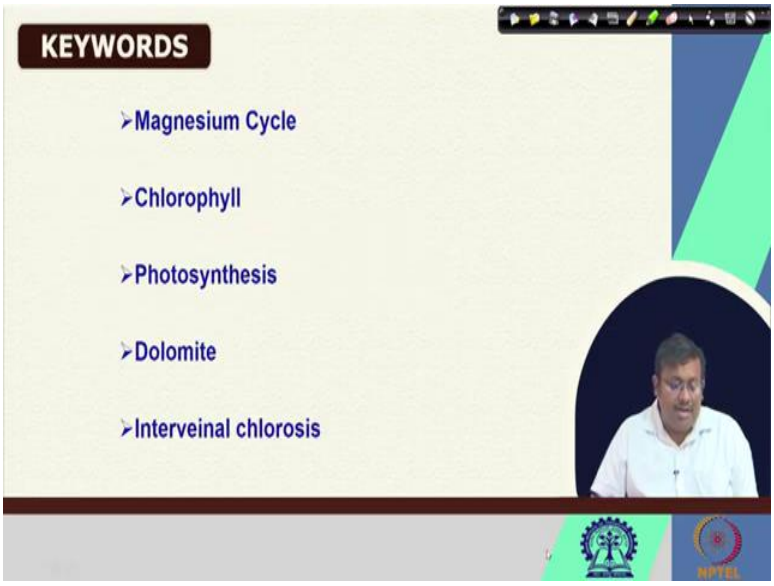

These are some of the keywords for this lecture - Magnesium cycle, chlorophyll photosynthesis, dolomite and interveinal chlorosis. So these are some of the some of keywords which we are going to discuss.

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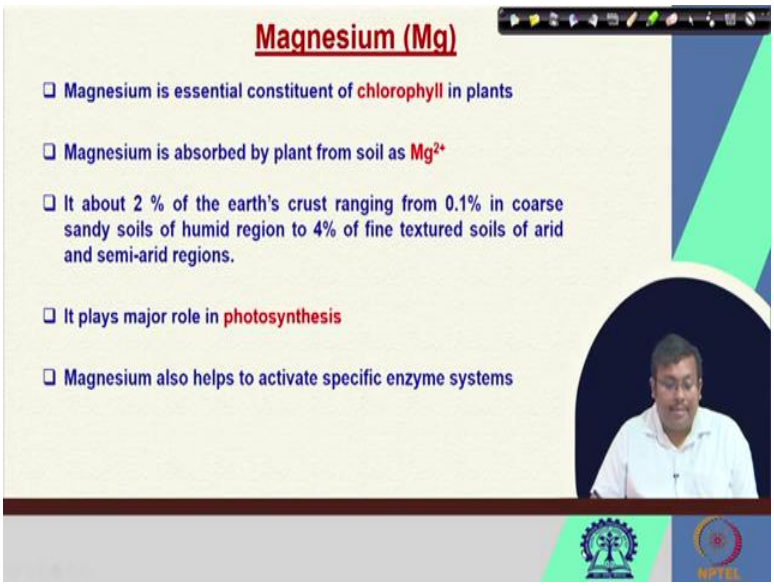

So magnesium - Magnesium which is denoted by Mg is essential constituent of chlorophyll implants. So it is a structural component of chlorophyll. And this suggests that it has tremendous role in the photosynthesis process. Because photosynthesis of the plant is dependent on the chlorophyll content. Without chlorophyll plant cannot complete its photosynthesis.

Now this can be easily implied that without photosynthesis plant cannot survive, so that is why magnesium takes part an important role for plant growth. Magnesium is absorbed by plant from the soil or plant roots uptake these nutrients as Mg2 plus form. It about 2 percent of the earth crust ranging from 0.1 percent in coarse sandy soils of humid region to 4 percent of fine textured soils of arid and semi-arid region.

Of course, in arid and semi-arid region you will see the higher content of calcium and magnesium. So, but in case of humid region you will see that the concentration of these calcium and magnesium goes down. So magnesium also helps to activate specific enzyme systems. So just like other essential elements it also helps in activating the specific enzyme systems.

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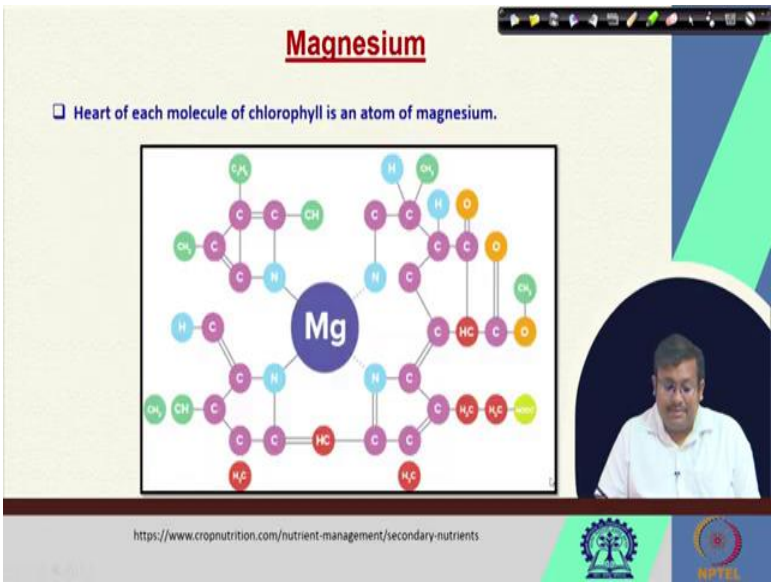

So if you see the structure of magnesium, we can see that magnesium is the central position, this cation which is surrounded by 4 pyrrole ring. So you can see this is a pyrrole, which is composed of four carbon atom and one nitrogen atom. So this four pyrrole ring is surrounding with a single magnesium atom and ultimately it is forming this chlorophyll molecule. So heart of each molecule of chlorophyll is an atom of magnesium. So that is why without the presence of magnesium we cannot think of photosynthesis process.

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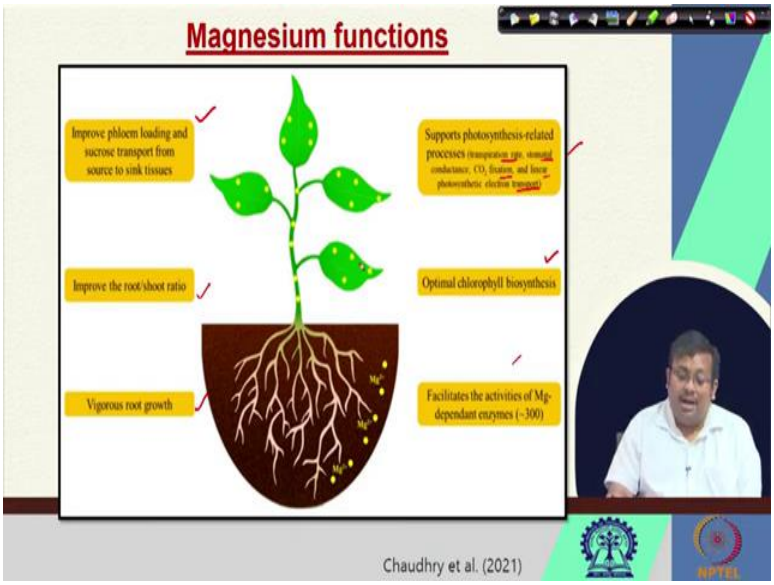

Now if we want to see the major functions of magnesium we can see that it improves the phloem loading and sucrose transport from source to sink tissues. Secondly it helps in vigorous root growth and improving the root to shoot ratio. So root growth is very much important and for root growth it is important that there should be adequate magnesium supply to the plant.

It also supports photosynthesis related process like transpiration rate, stomatal conductance, carbon dioxide fixation and linear photosynthetic electron transport; so all these are very much important for photosynthesis and they are controlled by this magnesium availability. Since it is a structural component of the chlorophyll.

So also it is clearly implied that magnesium is required for optimal chlorophyll biosynthesis. So without the presence of this magnesium chlorophyll biosynthesis will be severely hampered. It also facilitates the activities of magnesium dependent enzymes. There are almost 300 magnesium dependent enzymes in the plant body.

So without the presence of magnesium their activities are hampered, which ultimately impacts the growth of the planets. So we can see these are the major functions of magnesium within the plant so that is why plant cannot survive if magnesium is not present in the soil.

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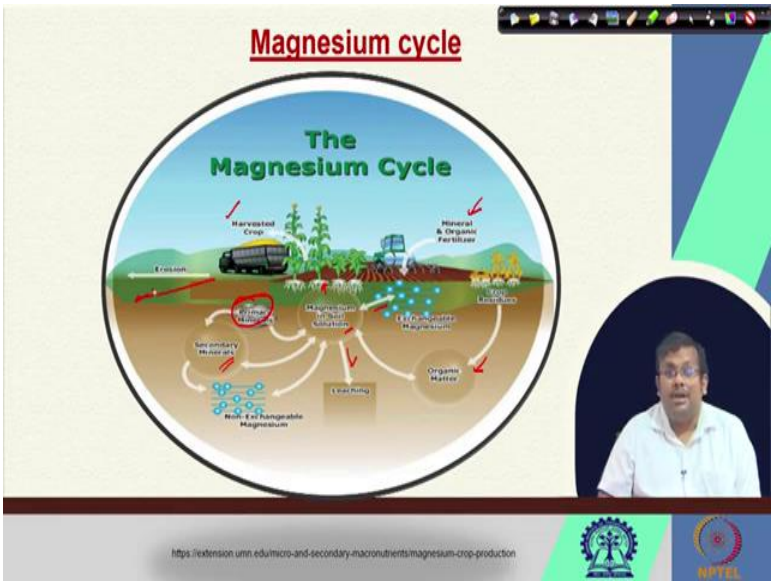

Now if you see this is the magnesium cycle. Now in the magnesium cycle you see there are different phases. So of course, the magnesium can be removed by crop harvest, so it is a example

of loss of magnesium. However, the input of magnesium can be achieved by mineral and organic fertilizers. So when we add this mineral organic fertilizer these magnesium ions get attached to the exchangeable positions of the clay minerals and from there it becomes available to the soil solution. From the soil solution plants uptake this magnesium.

So also the decomposition of the crop residues can add this organic matter and this organic matter is in equilibrium with this soil solution for supplying these magnesium ions. Some of this magnesium ion gets leached away and some of these magnesium ions can form these non-exchangeable magnesium.

Those non-exchangeable magnesiums are structurally integrated magnesium atoms. So these structurally integrated non-exchangeable magnesium can be also, we can see in case of different types of secondary minerals and the secondary minerals generally are coming from the weathering of the primary minerals. So this is how this magnesium can move in different phases within the soil and there it equilibrium with the magnesium in the soil solution.

Also magnesium can be lost by erosion from the soil. So these are some of the ways through which this magnesium cycle operates in the soil.

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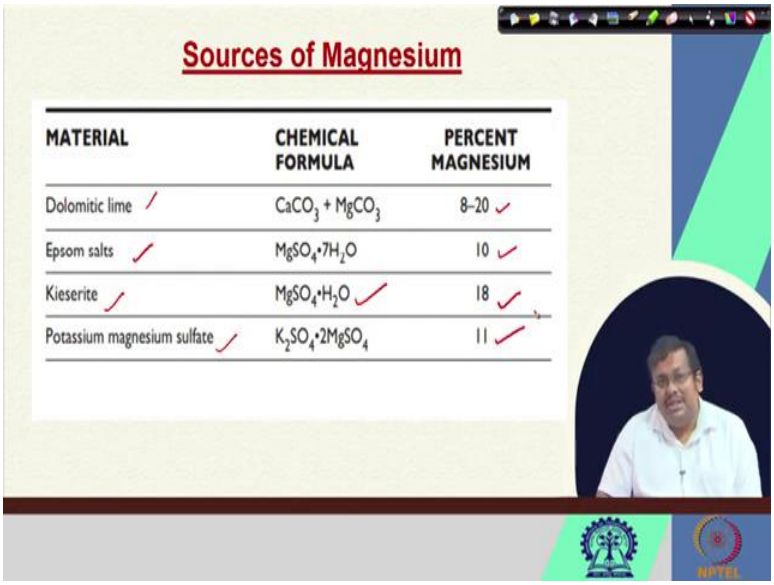

Now what are the sources of magnesium? So these are some of the minerals which are the general sources of magnesium like dolomitic limestone that is calcium carbonate plus

magnesium carbonate and it contains 8 to 20 percent of magnesium. Epsom salts which is magnesium sulphate hepta hydrate, which contain 10 percent magnesium.

Kieserite which is magnesium sulfate monohydrate contains 18 percent of magnesium. And potassium magnesium sulphate contains 11 percent of magnesium. So these are the common sources of magnesium.

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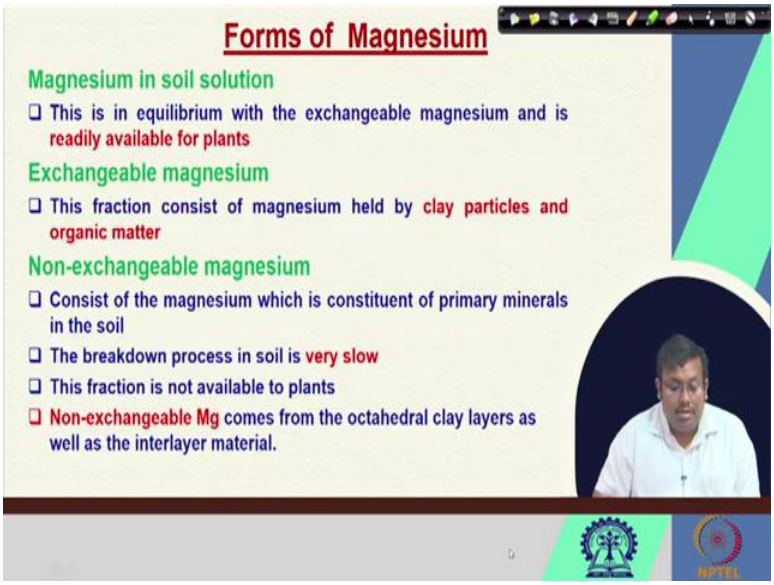

Now we have discussed in the magnesium cycle that there are different forms, so let us discuss those different forms. First of all, magnesium in soil solution. So this magnesium in the soil solution is in equilibrium with the exchangeable magnesium and is readily available for the plant. So whatever plant root uptake, whatever magnesium is up taken by the plant root they are coming from the soil solution.

They are available as Mg2 plus ion in the soil solution. Exchangeable magnesium - So this fraction consists of magnesium held by clay particles and organic matter. So this exchangeable magnesium is held by the clay particles and organic matter. In the exchangeable sites, due to the cation exchange capacity.

Now non-exchangeable magnesium consists of magnesium which is the constituent, the structural constituents of primary minerals in the soil. We have discussed it; we have seen in the in the magnesium cycle that the magnesium can also comes from the primary minerals due to the

process of weathering. However, the breakdown process or the weathering process in soil is very, very slow and this fraction is thus not readily available to the plants.

Another non-exchangeable magnesium is there which comes from the octahedral clay layers as well as the inter layer material. So in our, if you have gone through my Soil Science Technology lectures where we have discussed about the structure of the clay minerals. We have seen that there are two types of structure, one is di-octahedral structure as well as tri-octahedral structure.

In case of tri-octahedral structure, out of the three octahedral positions are filled by magnesium. However, in the di-octahedral orientation two of the three octahedral positions are filled by aluminum ions. So in the tri-octahedral structure this magnesium appears as a structural component. And thus, it is non-exchangeable. It cannot be utilized by the plants, so this is in the non-exchangeable form.

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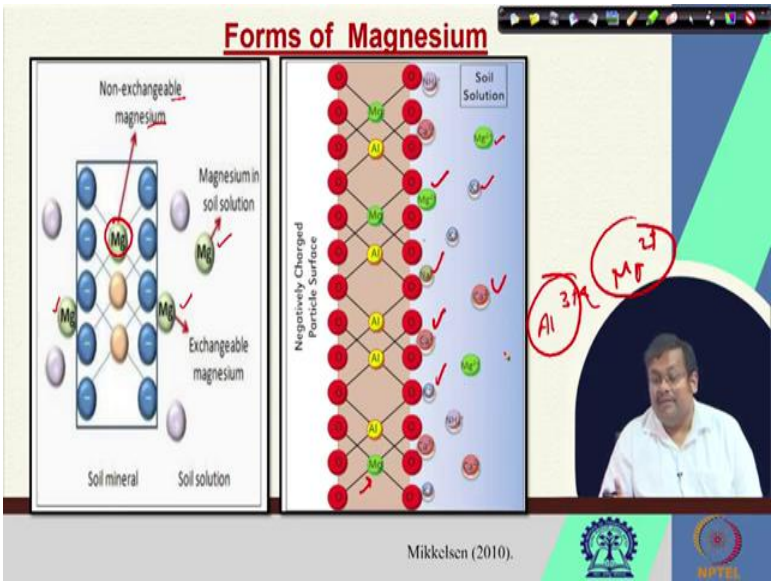

So you can see these are the forms of magnesium. We can clearly see. So these are the, this is the magnesium in the soil solution, which is freely moving in the soil solution. These are the exchangeable magnesium, which are attached to the exchangeable sides of the clay. However, these is the non-exchangeable magnesium, which is a structural component forming the octahedral sheet like structure.

So this is non-exchangeable magnesium. So also, this picture also shows this magnesium, potassium, calcium, these are in soil solution and due to the format… due to the CAC or Cation Action Capacity that are being formed, these ions are attached to the surface of the clay minerals. Also if you can remember we are seeing here in the octahedral sheet isomorphous substitution where one aluminum is replaced by magnesium.

Now we know that aluminum is 3 plus which is replaced by magnesium 2 plus, so when there is replacement of 3 plus with 2 plus there will be formation of negative charge and this negative charge is satisfied by these positively charged cations in the exchange sites, so that is why this distribution can be seen.

Either magnesium could be a structural component of the whole octahedral sheet forming a tri-octahedral structure or in this di-octahedral structure also aluminum can be replaced by magnesium due to the isomorphous substitution and ultimately creating negative charge which will attract this positively charged cations of which magnesium is there and sodium calcium there, potassium there, so they are getting attached.

And also the some of them are also in the soil solution, so we can understand that due to this isomorphous substitution CEC develops and CEC helps in attaching these mineral or this positively charged cations and some of the cations are in the soil solution. So the distribution of different forms can be clearly seen and that with the reason of their distribution.

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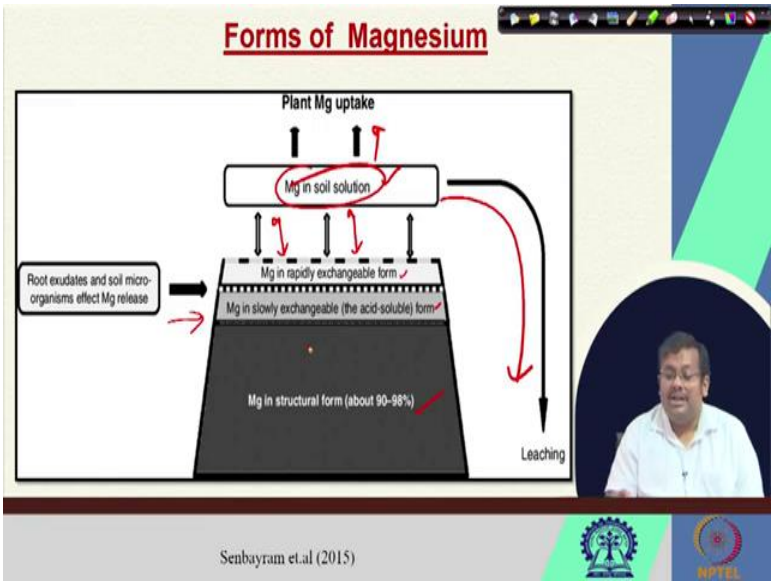

Now also we can clearly see here forms of magnesium in another perspective. So here we can see that magnesium in the structural form consist about 90 to 98 percent. So magnesium is slowly exchangeable in the acid soluble form and also magnesium is rapidly exchangeable form magnesium in soil solution.

So the exchangeable sides, the magnesium which are attached to the exchangeable sides can be in equilibrium with the magnesium and the solution and from where magnesium is uptaken by the plant. From these magnesium in the soil solution magnesium can be lost by leaching and also root exudates and soil microorganisms affect the magnesium release.

So this plant magnesium uptake depends on this magnesium in the soil solution and magnesium in the soil solution is in equilibrium with the exchangeable magnesium. However, non-exchangeable magnesium or structural magnesium are not readily available to the plants. And their conversion is also very slow.

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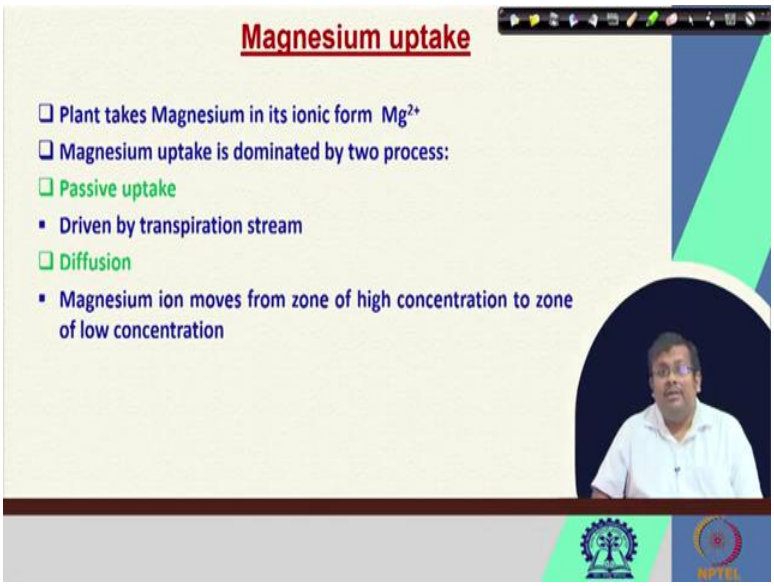

Now let us see and let us discuss about magnesium uptake. Now we know that plant takes magnesium in its ionic form that is Mg2 plus and magnesium uptake is dominated by two processes, one is passive uptake, which is driven by transpiration stream, another is diffusion, where magnesium ion moves from zone of high concentration to zone of low concentration along the concentration gradient, we know that.

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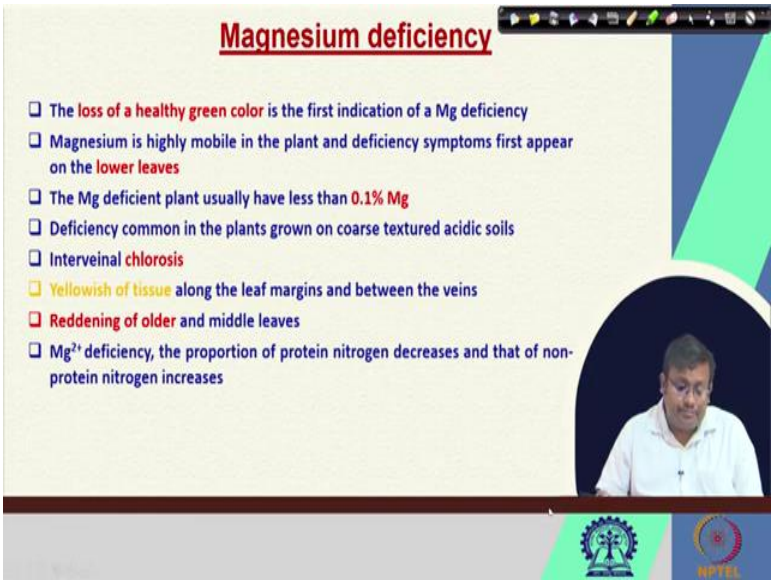

So the loss of a healthy green color is the most, in the first indication of also magnesium deficiency. So now we are discussing the deficiency symptoms. We can see since magnesium is a component of chlorophyll magnesium deficiency will also affect the chlorophyll synthesis and as a result there will be loss of this healthy green color.

So this is the first indication of magnesium deficiency. Magnesium is also highly mobile in the plant and deficiency symptoms first appear on the lower leaves. And the magnesium deficient plant usually have less than 0.1 percent magnesium and deficiency is common in the plants grown on coarse texture acidic soil.

Because of course, in case of acidic soil we cannot see high concentration of calcium magnesium. They are mostly present in in alkaline condition. And we can also see interveinal chlorosis in case of magnesium deficiency. Yellowish of tissue along with the leaf margin and between the veins we can, yellowish patches of tissues along with the leaf margins and between the veins we can see.

Reddening of the older leaves and middle leaves are also important deficiency symptoms. And also magnesium deficiency, in case of magnesium deficiency the proportion of protein nitrogen decreases and that of non-protein nitrogen increases. So these are some of the magnesium deficiency symptoms.

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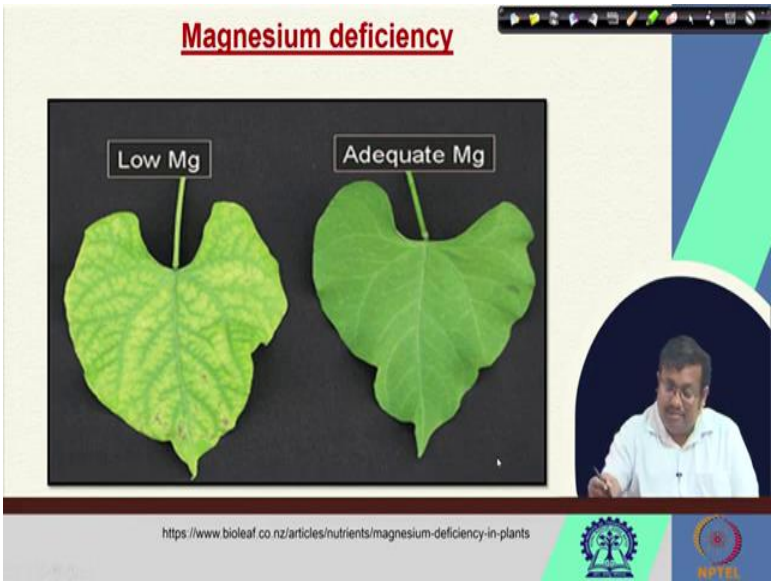

So these are some of the pictures showing the magnesium deficiency, you can see it is a low magnesium, so it is showing interveinal chlorosis and here adequate magnesium, so no interveinal chlorosis.

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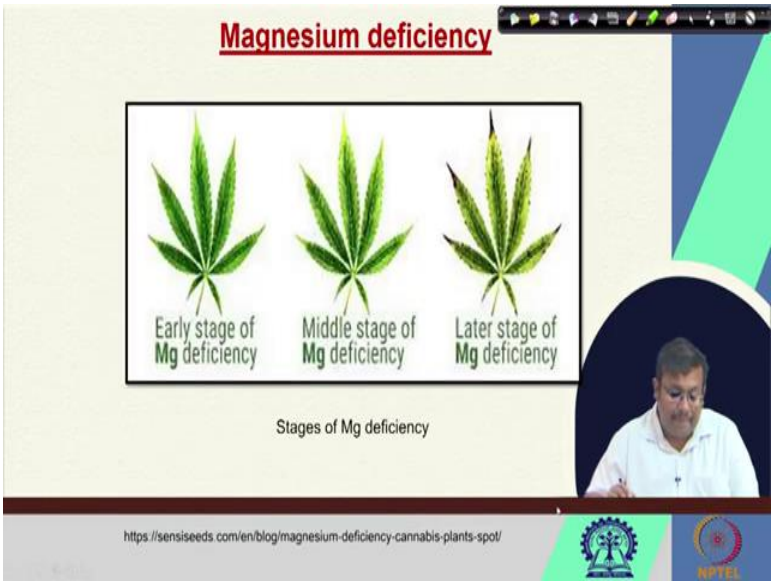

Also here you can see different stages of magnesium deficiency, so this is an early stage of magnesium deficiency. As the stage progresses we can see the yellowing is progressing. So more interveinal chlorosis we can see at the later stage of magnesium deficiency.

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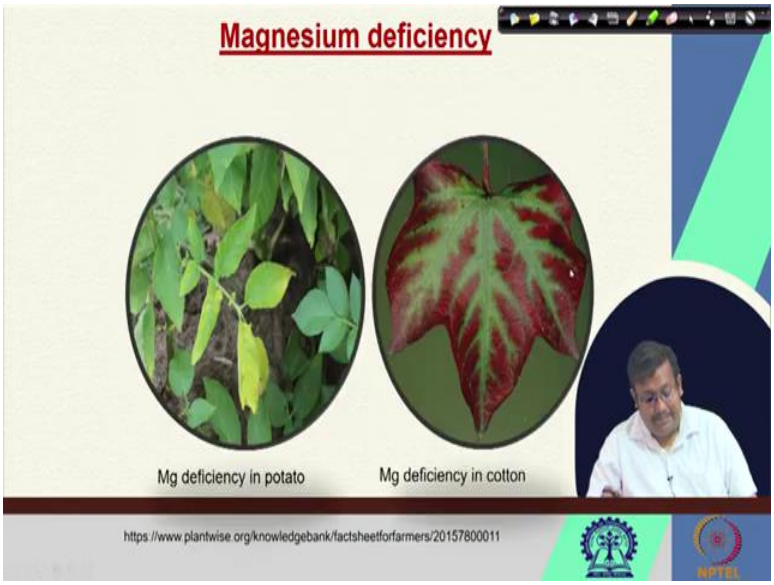

Here we can see internal chlorosis in case of magnesium deficiency in potato and magnesium deficiency in cotton we can see here.

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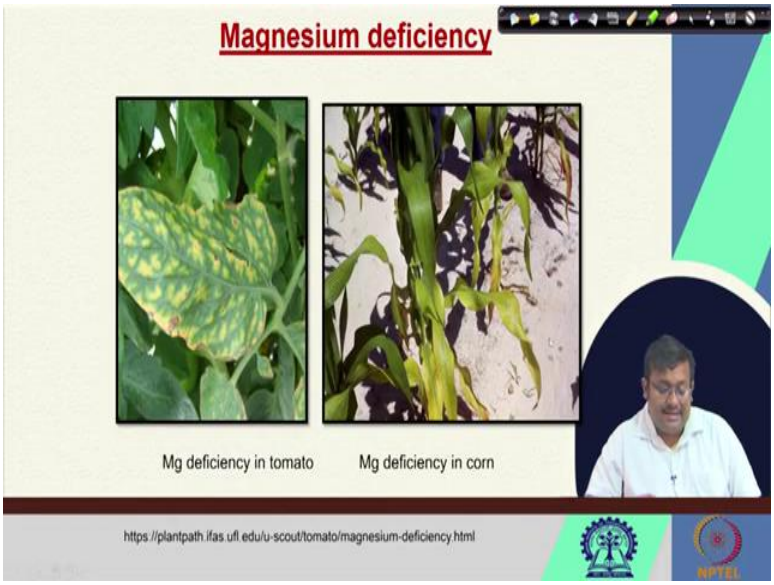

This is the magnesium deficiency in tomato and here you can see magnesium deficiency in corn.

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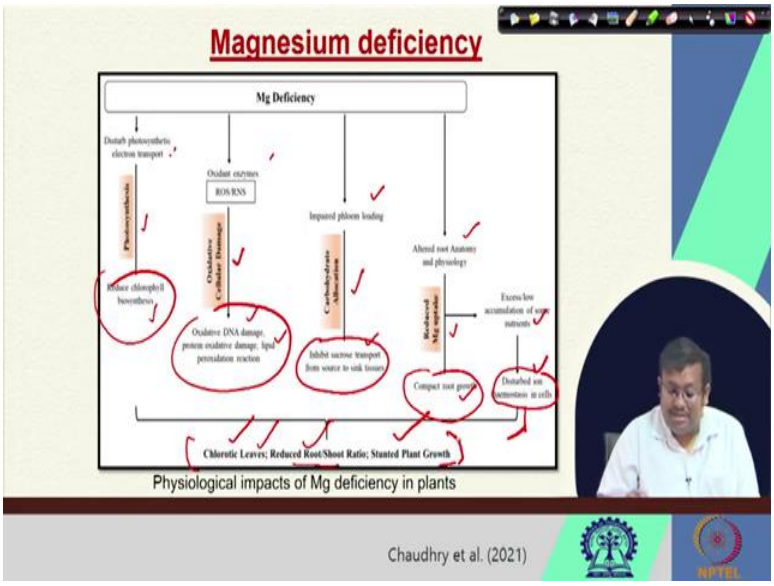

So if you want to see the physiological impacts of magnesium deficiency in plants, so we can see there are different types of implication. First of all, when there is a magnesium deficiency that

affects the photosynthesis, because this disturbs the photosynthetic electron transport. Due to this magnesium deficiency and which affects the photosynthesis and reduce the chlorophyll biosynthesis, it is the first thing.

Second is it affects the oxidant enzymes and this oxidative cellular damage can occurs and ultimately there is oxidative DNA damage, protein oxidative damage and lipid peroxidation reaction can occur. Also it can impair the phloem loading, which can impact the carbohydrate allocation, which inhibits the sucrose transport from source to sink tissues. Also magnesium deficiency can alter root anatomy and physiology.

So ultimately which leads to reduced magnesium uptake and compact root growth and also they can produce excess or low accumulation of some nutrients. And they can disturb iron hemostasis in soil. So ultimately from this reduced chlorophyll biosynthesis oxidative DNA damage, protein oxidative damage lipid peroxidation reaction.

Then inhibition of sucrose transport from source to sink tissues, compactness of root growth and then disturbed iron hemostasis in cell; ultimately leads to chlorotic leaves, reduce root to shoot ratio and stunted plant growth. So all these comes, all these affect these plant in this fashion where we can see chlorotic leaves, reduce root to shoot ratio, because root growth is severely hampered and also stunted plant growth. So these are some of the ways to which the magnesium deficiency affect the plants.

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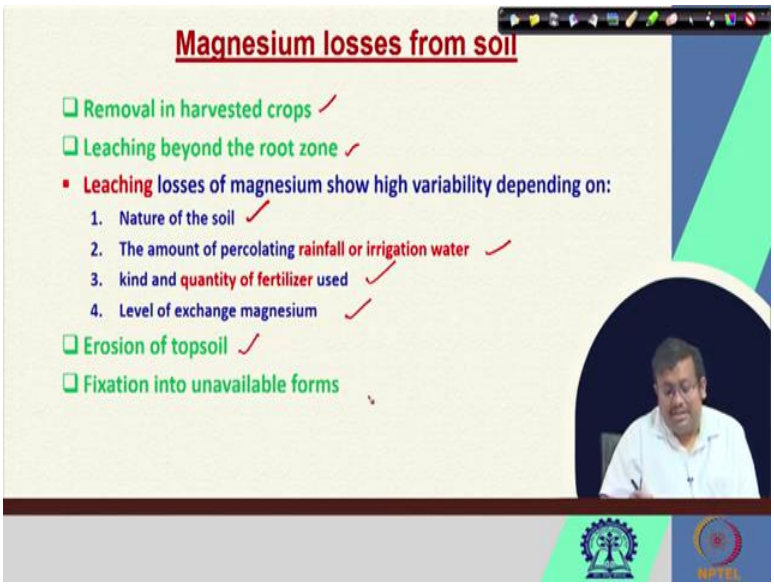

So magnesium losses from soil. The major loss we can see in case of crop uptake or crop removal, leaching also beyond the root zone is another important ways through which magnesium gets lost from the soil. So leaching losses of magnesium show high variability, which is dependent on the nature of the soil.

The amount of percolating rainfall or irrigation water, kind and quantity of fertilizer used and level of exchange of magnesium also magnesium loss from depends on erosion of topsoil and also fixation into unavailable forms. So these are some of the, these are some of the ways which magnesium gets lost from the soil.

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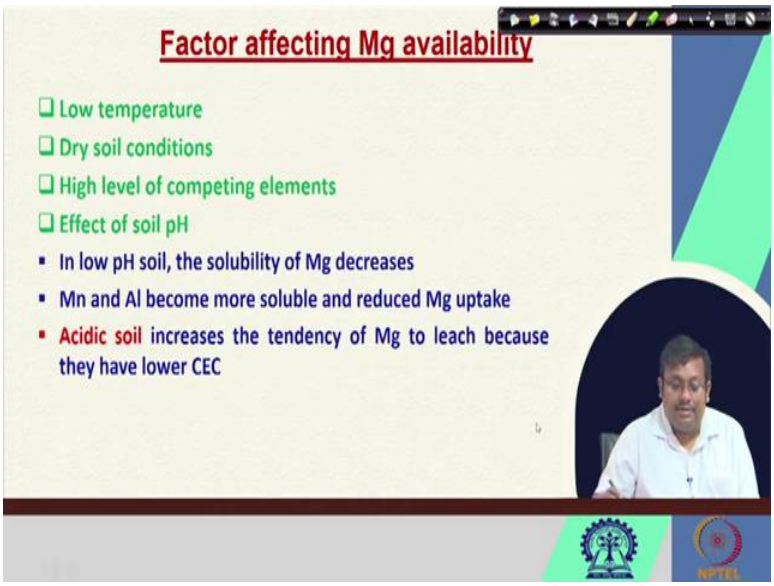

Also there are some factors which affect the magnesium availability. First of all, low temperature, dry soil condition, high level of competing elements and effect of soil pH, these are all important factors which affects the magnesium availability. Now in low pH soil the solubility of magnesium decreases, manganese and aluminum became more soluble and reduce the magnesium uptake.

So acidic soil increases the tendency of magnesium to leach, because they have lower CEC. So these are some of the reasons where we can see this magnesium deficiency in case of low pH acidic soils.

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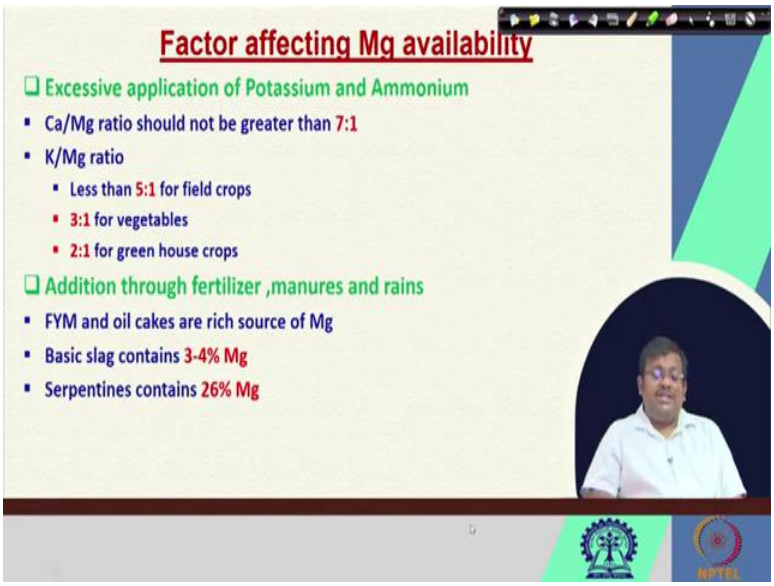

Excessive application of potassium and ammonium also impacts the magnesium availability, because calcium magnesium ratio should not be greater than 7 is to 1 and potassium magnesium ratios is less than 5 is to 1 in field crops and 3 is to 1 for vegetables and 2 is to 1 for green house crops. So addition through fertilizer, manures and rains also impacting the magnesium availability, because farmyard manure and oil cakes are rich source of magnesium.

Basic slag contains 3 to 4 percent of magnesium and serpentine contains 26 percent of magnesium. So these are some of the factors which affect the magnesium availability.

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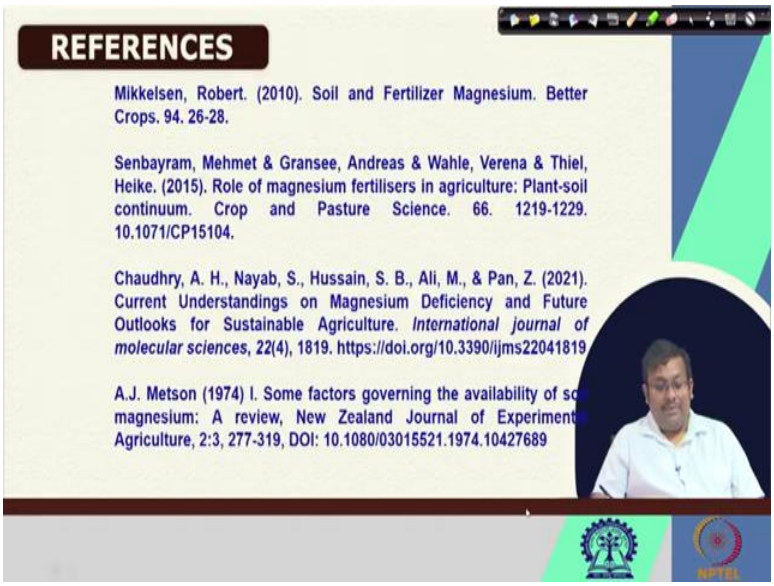

So guys let us wrap up this lecture and these are some of the references which I have consulted for this lecture. Please go through these and these different sources to gather more comprehensive idea about magnesium. And I hope those will be helpful for your better understanding of magnesium and their impact on plant growth and metabolism. So let us wrap up this lecture and let us meet in our next lecture. Thank you.