Soil Science and Technology
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Lecture - 31
Essential Plant Nutrients

Welcome friends to this week-7 lecture series of Soil Science and Technology. And in this lecture series, I mean in this coming 5 lecture series, we will discuss about the different types of essential plant nutrients, and you know their functions. And the first topic, we will cover that is the essential plant nutrients.

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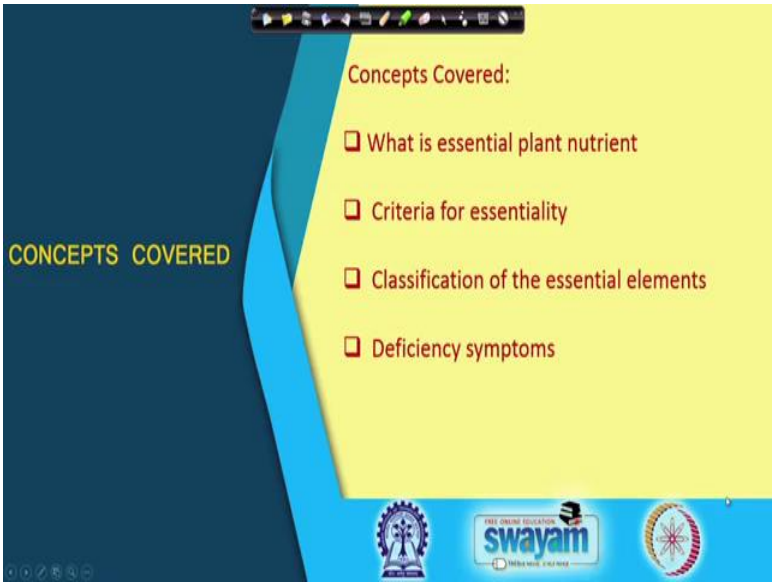

And we will cover several aspects in this lecture, and the basic aspects which we will cover are what is a essential plant nutrients and what is the what are the criteria for essentiality, how we consider a particular element as an essential plant nutrient and then how we can classify the different essential elements, and finally we will see some deficiency symptoms of different essential nutrients.

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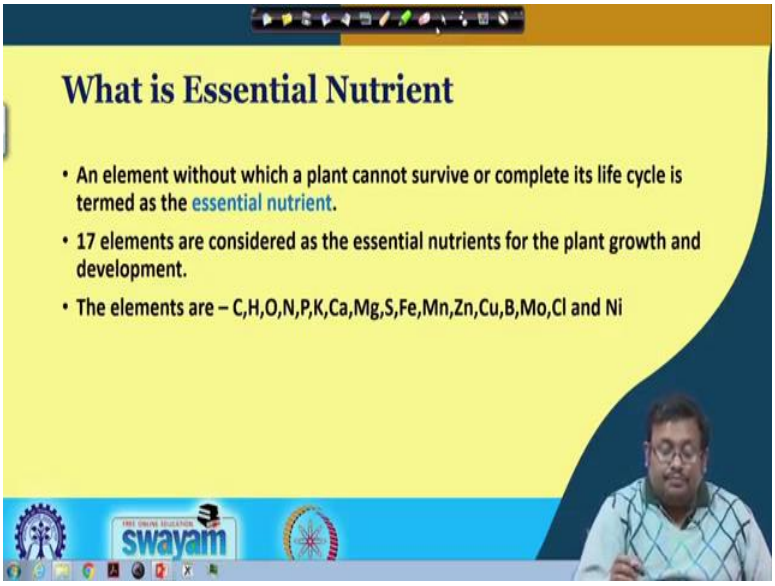

So, guys let us start. And so what is an essential element or essential nutrients. Sometime, we will use this term interchangeably essential element or essential nutrient now. An element without which a plant cannot survive or complete its life cycle is termed as an essential element essential nutrient or essential element.

Now, you remember that there are 17 elements, which are considered as a essential nutrient for the plant growth and development and these are basically these 17. So, these 17 starts from carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, zinc, copper, boron, molybdenum, chlorine, and nickel.

So, remember these 17 elements are considered as essential nutrients for the plant, because plant cannot complete its life cycle without these 17 essential elements. Regardless of their quantity required, so we will discuss each of them you know each of them individually in the current in the coming slides.

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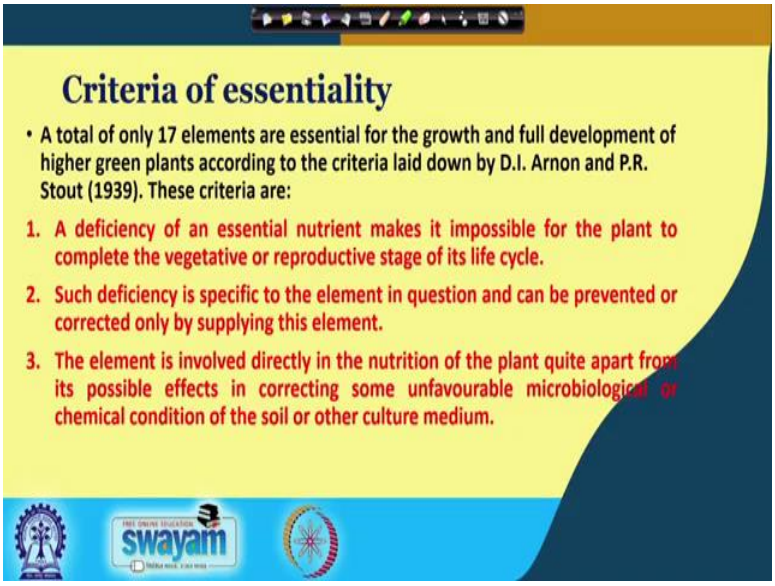

So, let us go, and see what are the criteria based on which we can term in a particular element as an essential plant nutrient. Now, you know that total of 17 elements are essential for growth of the full development of higher green plant. And these criteria of essentiality were given by two scientist called Arnon and Stout in the year 1939.

And these three criteria are first of all a deficiency of an essential nutrient makes it impossible for the plant to complete the vegetative or reproductive stage of its life cycle, so this is the first one. The second one is you know such deficiency specific to the element in questions and can be prevented or corrected only by supplying this element. And finally, the element is involved directly in the nutrition of the plant quite apart from its possible effects in correcting some unfavorable microbiological or chemical condition of the soil or other culture medium.

So, in other words a you know this three criteria's are first of all the deficiency of that particular element will make you know you know, if there is a deficiency of that particular element plant cannot survive or plant cannot complete its life cycle. This is the first criteria. Second criteria is the role of a specific element cannot be corrected by supplying other element, so the role is very very specific. And third this element must be involved in plant metabolism. So, these are very very important criteria's for considering a particular element as an essential or not essential. So, based on these criteria's, we have selected the 17 elements as essential plant nutrients.

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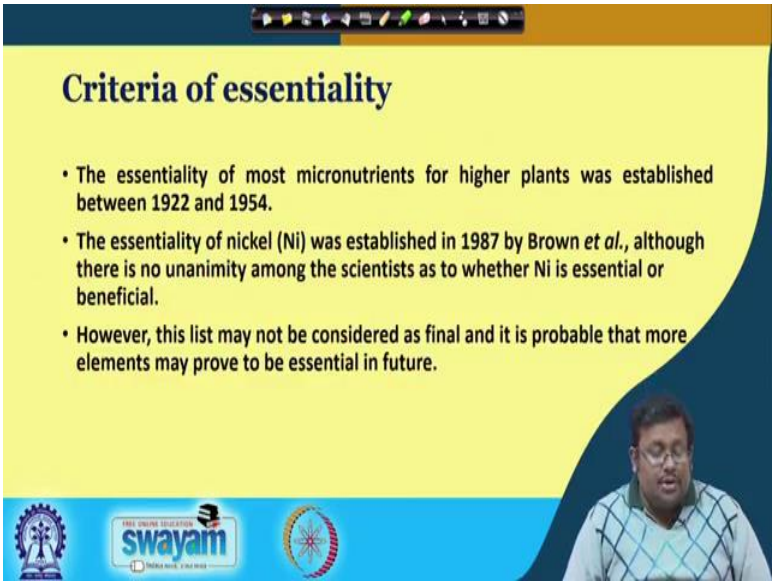

So, the essentiality of the most micro nutrients for higher plants were established between 1922 to 1954. And the essentiality of nickel was established you know it is the latest established essential nutrient, I know it was established in 1987 by Brown et al, although there is no unanimity among the scientist as to whether nickel is essential or beneficial.

However, we will not go to that, we will not go that you know argument, and we will consider nickel as an important plant element or an important essential element. So, the list may not be considered we remember that however you know, although we have we are considering 17 elements as essential plant elements. However, this list may not be considered as final, and it is possible that more elements may prove to be essential in future, because it is a continuous discovering process.

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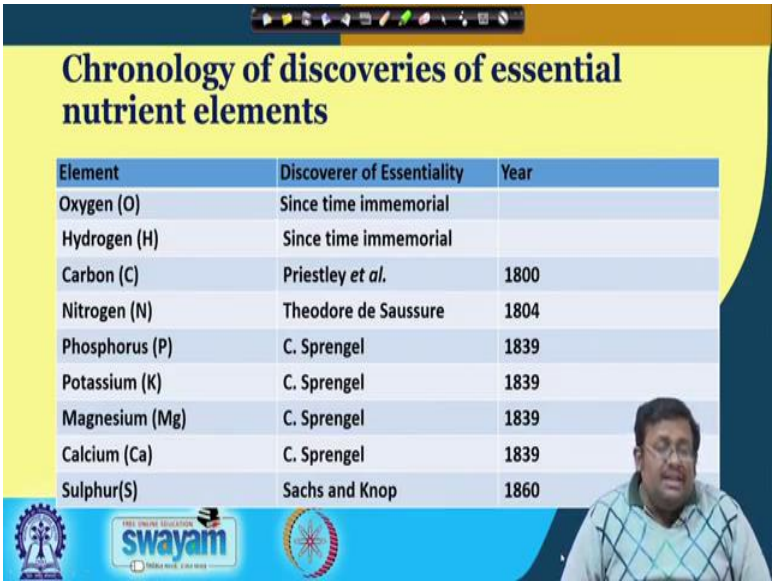

So, let us see what is the chronology of discoveries of essential nutrient elements of the plants. So we will see in which year the essentiality criteria or essentiality of that particular element was discovered or established by certain scientific groups or research groups.

So, you know let us start with the, you know the oxygen, and these oxygen you know it its discovery has been you know you know since time immemorial. So, we do not know exactly which year its establishment were you know its essentiality was established and similarly, for hydrogen.

And in case of carbon, it was established by Priestley et al in 1800. And in case of nitrogen you know it was first established by Theodore de Saussure in eighteen hundred you know four and phosphorus by Sprengel in 1839 and also potassium and magnesium and calcium by Sprengel in 1939. So, Sprengel has established the, you know the Sprengel has established the essentiality of these four important minerals that is K, K, Mg, and K, Ca. And as far as sulphur is considered, it is essentiality was established by Sachs and knop in 1860.

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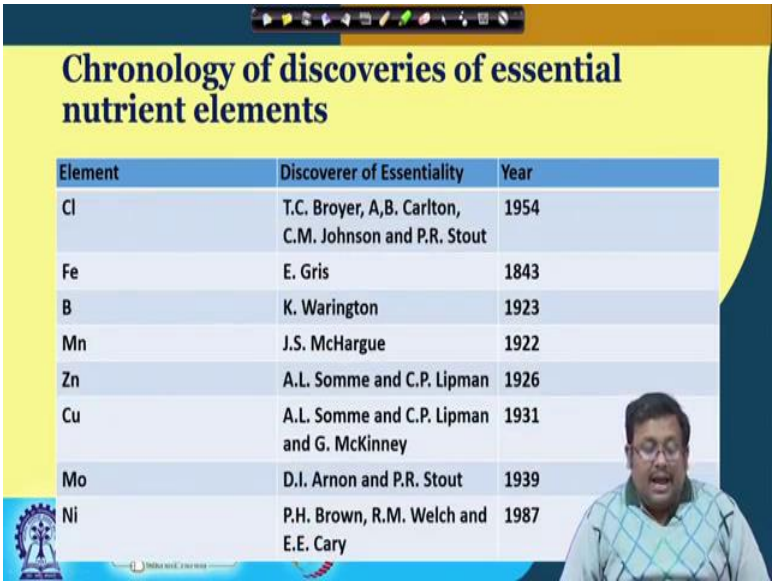

And the in case of chlorine, it was established by T.C. Broyer, A,B. Carlton, Johnson and stout in the year 1954. And iron was by E.Gris in 1843. Boron by Warington in 1923 and manganese by McHargue in 1922 and zinc by Somme and Lipman by in 1926.

Copper by again Somme, Lipman, and McKinney in 1931. And molybdenum by Arnon and Stout who has given that essentiality criteria, and it was in 1939. And the latest one is nickel by Brown Welch and Cary in the year 1987. So, these shows this list shows basically the chronology of establishment of essentiality criteria of those establishment of essentiality of these 17 essential plant nutrients.

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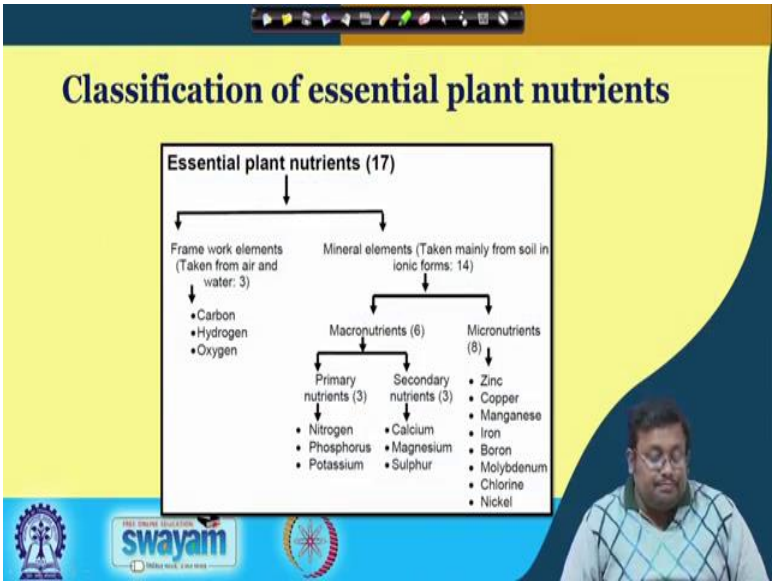

So, once you know that okay these 17 are the important or essential plant nutrients. Now, let us divide them into several classes based on their relative importance or relative amount needed by the plant for maintaining their vegetative and reproductive cycle. So, if we start with the 17 elements broadly, we convey we can we can classify these 17 elements into two groups. One is called the frame work elements, and taken you know the frame work elements are basically the carbon, hydrogen, and oxygen. And basically these three type of elements are you know taken from air and water, we will discuss this later on.

And these frame work elements are required for you know for the production of cellulose, and other building block the molecules for plant body. And the other elements basically we call other the 14 elements we call them mineral elements, because they are basically taken in ionic forms and or mineral form. And we can divide further divide those minerals into two groups. One is called the macro nutrients, and other is micro nutrients based on the relative amount needed by the plant to maintain their life cycle.

So, there are 6 macro nutrients, and only 8 micro nutrients. So, 6 macro nutrients are again sub divided into primary nutrients and secondary nutrients. So, there are three primary nutrients, and there are 3 secondary nutrients. And remember that these primary 3 nutrients that is nitrogen, phosphorous, and potassium required in you know higher

quantity than other elements. And that is why, these 3 elements that is nitrogen, phosphorous, and potassium are the common element, which are present in fertilizers.

And secondary nutrients are calcium, magnesium, sulphur, and these elements are required in moderate quantity. However, micro nutrients are required in minute quantity, however they are you know they are essential, so that means you know the irrespective of their you know little amount needed by the plant they are essential. So, if they are you know if they are not present inside the soil that will reflect in their deficiency symptoms in the plant in the plant system.

So, the micro nutrients are basically 8. Starting from zinc, then copper, then manganese, then iron, then boron, molybdenum, chlorine, and nickel, so that is why you know this chart you know this slide shows basically the classification of essential plant nutrients. So, I hope that now it is clear. So, let us move ahead.

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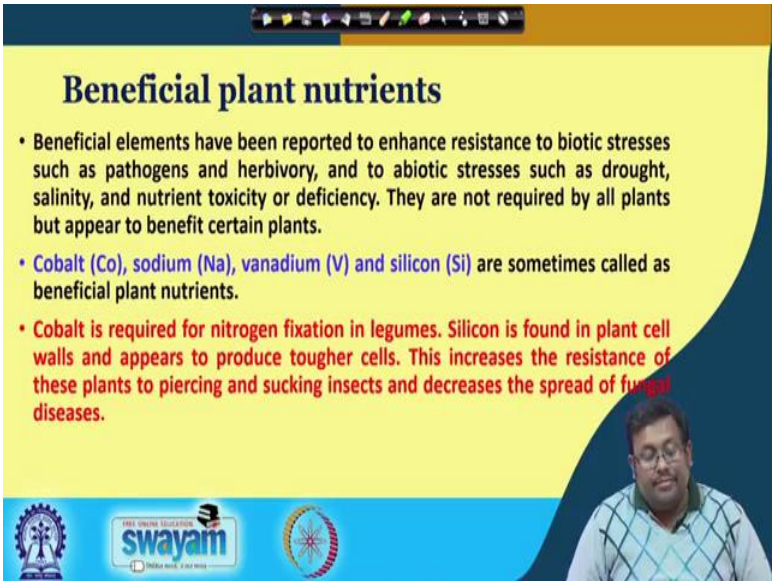

And see what are the other beneficial plant nutrients. So, there is a basic difference between essential plant nutrients and beneficial plant nutrients. Now, beneficial elements have been reported as you to enhance resistance to biotic stresses such as pathogen and herbivory, and to abiotic stresses such as droughts, salinity, and nutrient toxicity or deficiency. And they are not required by all the plants, but appear to benefit certain plants.

So, they are they are beneficial to certain plants, they are not required by all the plants, so that is why they are not considered as essential plant elements. However, they show several benefits for certain plants, so that is why they are called beneficial plant nutrients. So, what are these beneficial plant nutrients there are 4 to 5 beneficial plant nutrients specially cobalt, sodium, vanadium, and silicon. So, these four are sometime called as beneficial plant nutrients.

And remember that cobalt is required for nitrogen fixation in legumes. And we will discuss about the nitrogen fixation by legumes crop in coming lectures. And silicon is found in plant cell walls and appear to produce tougher cells. So, it helps in you know protecting the cells by you know making the plant cell wall more sturdy, and this increases the resistance of these plants. So, when the silicon is present in the cell wall, and make it sturdy and hard enough, it increases the resistance of these plants to piercing sucking insects and decreases the spread of fungal diseases, so that is why this you know the silicon is also considered as an beneficial plant nutrient for certain plants.

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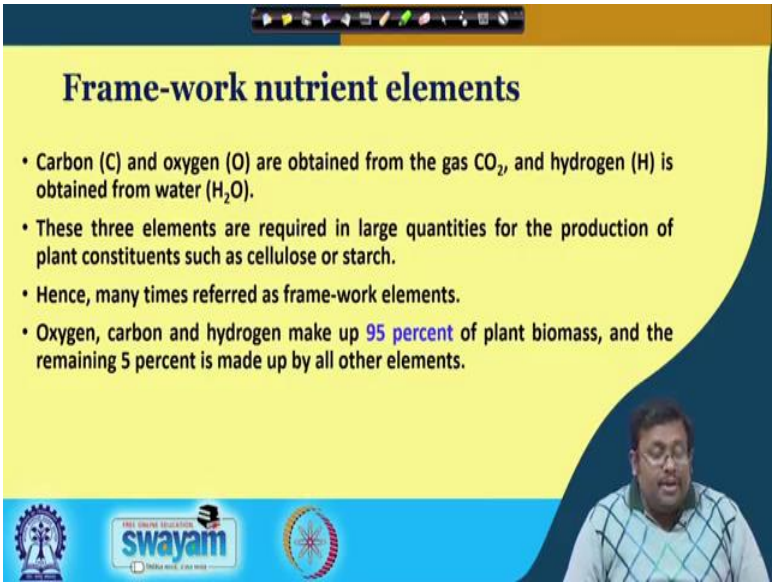

So, let us let us also discuss the frame-work nutrient elements that the frame-work nutrient elements are basically these three carbon, oxygen, you know and hydrogen. Now, the carbon and oxygen basically plants are getting from the gases carbon dioxide in the process of photosynthesis. However, the hydrogen is obtained from the water also in

the process of photosynthesis. So, these three elements plants are getting directly from the air and water.

And these three elements are required in large quantities for the production of plant constituents such as cellulose or starch, I have already told you. And many times they are referred as a frame work elements. So, oxygen, carbon, and hydrogen makes up remember 95 percent of plant biomass, and the remaining 5 percent only made by all other elements, so that is why they are frame work elements. And they are required in major quantity of plant biomass, and only 55 percent is required by only 5 is made up by all the other you know mineral nutrient.

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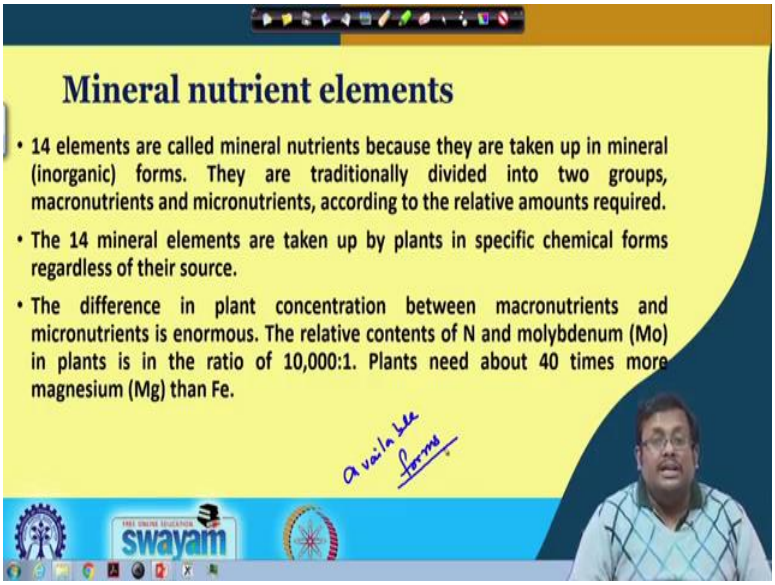

So, let us see, what are you know what are the different features of mineral nutrients. So, 14 mineral nutrients we have already shown you, and they are called mineral nutrients, because they are taken up by mineral form or inorganic form. And they are traditionally divided into two groups like macro nutrients and micro nutrients, I have already told you, and according to the relative amount of required.

So, this 14 mineral elements are taken by plants by specific chemical form regardless of their source this is very important. For example, nitrogen is essential plant elements or you know it is an important macro nutrient or primary nutrient. And this nitrogen is present in soil in different forms organic forms, inorganic forms.

However, either plant can only you know uptake nitrogen in two forms nitrate or ammonium forms. So, these two forms are considered as available forms of nitrogen, so it does not matter if the soil has high amount of total nitrogen that does not show the availability to the plant. Plant is the growth and yield and nutrition of plant is depended on the available fraction of the total elements.

So, similarly is also true for other element just like in case of phosphorous, you know you know phosphorus is you know is taken by the plant by either primary orthophosphates and secondary orthophosphates. So, these two are the available forms of phosphate for the plants. So, these 14 elements are taken up by the plants in specific chemical forms regardless of source, so we call them available forms. We will discuss the available forms later in this lecture, what are the available forms for individual mineral.

Now, the difference in plant concentration between macro nutrients and micro nutrients is enormous. Obviously, I told you the basic idea behind dividing these elements or the mineral nutrients into macro elements and micro elements is the relative amount required by the plant.

So, the relative contents of nitrogen and molybdenum in plants is in the range of 10,000 is to 1. So, plant is about 40 times more magnesium than Fe. So, I mean you can have an idea about the differences between macro nutrients and micro nutrients or relative quantity of the macro nutrients or micro nutrients required by the plant.

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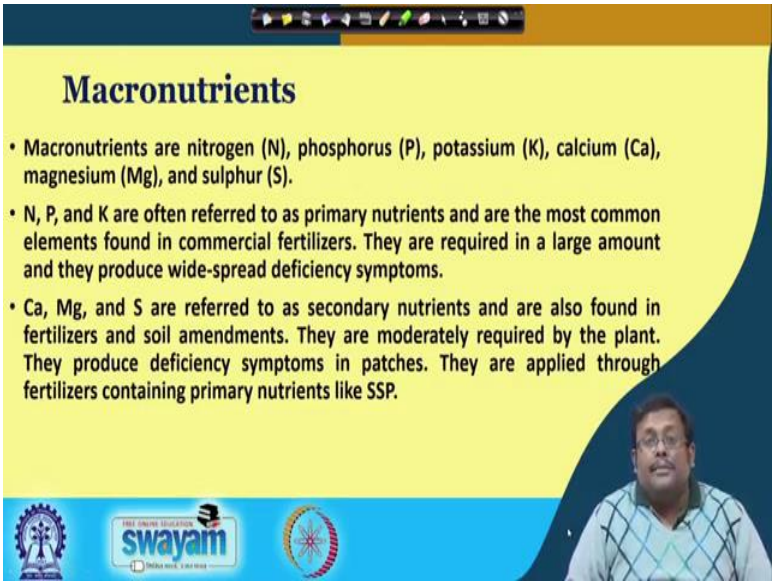

So, let us talk about the macro nutrients. Macro nutrients are basically you know there are six macro nutrients, starting from nitrogen, phosphorous, potassium, calcium, magnesium, and sulphur. So again nitrogen, phosphorous, potassium, calcium, magnesium, and sulphur.

And N, P, K are often considered to as a primary nutrients, because they are required they are the most common elements found in commercial fertilizers. And they are required in large amount and they produce wide-spread deficiency symptoms. So, most of the deficiency symptoms which you can see in the plant due to mineral deficiency are coming from this either N, P, and k deficiency.

And also calcium, magnesium, sulphur are referred as a secondary nutrients as they are also found in fertilizer and soil amendments. And they are moderately required by the plant. And they produce deficiency symptoms in patches, and they are applied through fertilizers containing primary nutrients like Single Super Phosphate or SSP. Now, the single super phosphate apart from you know apart from supplying the phosphorus, it also supplies the sulphur. So, this is the secondary element, so that is why it can support it can it can supply both primary and secondary nutrient to the plant.

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Now, micro nutrients are you know there are eight micro nutrients, then iron, manganese, zinc, boron, copper, chloride, and molybdenum, and nickel. And micro nutrients are required in relatively very minute quantities. But, they are regardless of their quantities again I am saying they are essential, even if they are required in very minute quantities their presence in their absence will go will you know their absence will cause deleterious effect in plant life cycle and plant cannot complete its life cycle without their presence.

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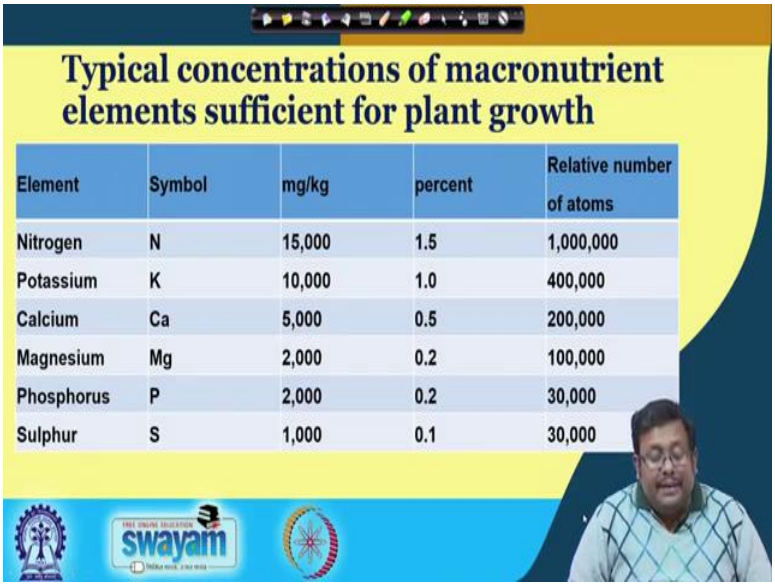

So, so what are the typical concentration of macro nutrients sufficient for plant growth. Let us see in this table you can see here, the nitrogen is required in 15,000 ppm or 1.5 percent relative number of atoms is almost you know 1,000,000. And obviously, potassium is 10,000 ppm and 1 percent and 400,000. And calcium you know 5,000 ppm or 0.5 percent and 200,000 atoms.

And magnesium 2000 ppm 0.2 percent and 100,000 ppm 100,000 of atoms. In case of phosphate you know 2000 ppm, and obviously 0.2 percent and 30,000 number of atoms. In case of sulphur, it is 1000 ppm and only 0.1 percent and it contains 30,000 atoms, which is relatively number of atoms.

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So, so relative concentration essential plant nutrients some you know some micro elements also can be toxic for plants at level only somewhat higher than the normal. So, in the majority of the cases this happens when the pH is low to very low. So, when the pH is very low to very low some micro nutrients are there, which shows toxicity. For example, you know manganese is one of the one of the important micro nutrient, which shows toxicity in acid soil. So, aluminum and manganese toxicity are the most frequent ones, in direct relation to the acid soil. So, manganese is an you know is an essential micro nutrient for the plant.

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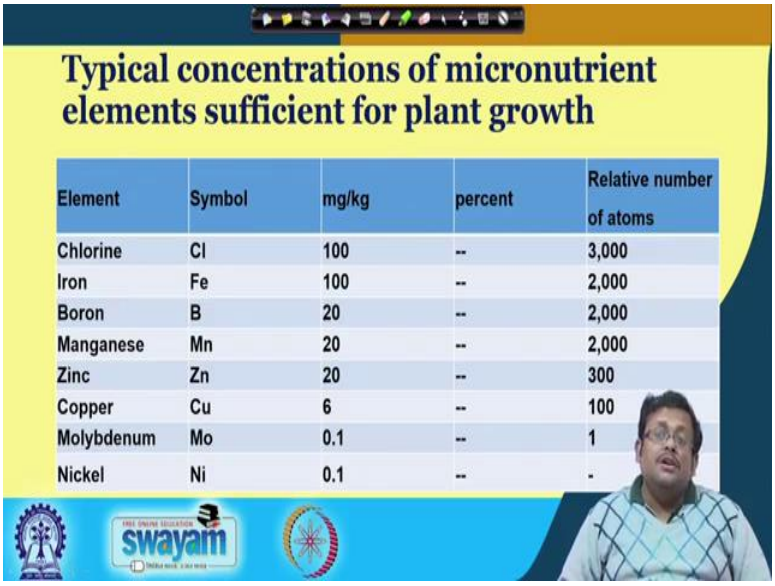

Now, if you see the typical concentration of micro nutrient elements sufficient for plant growth, you will see for chlorine is only 100 ppm. And it is for iron it is also 100 ppm, boron is only 20 ppm, manganese is 20 ppm, and then copper zinc is 20 ppm, copper is 6 ppm. And molybdenum and nickel is required in you know in the lowest quantity that is almost 0.1 ppm. See you can see among the all the micro nutrients also the relative you know relatively chlorine, and iron is required in higher quantity that is 100 ppm as compared to the other six micro elements or micro nutrients.

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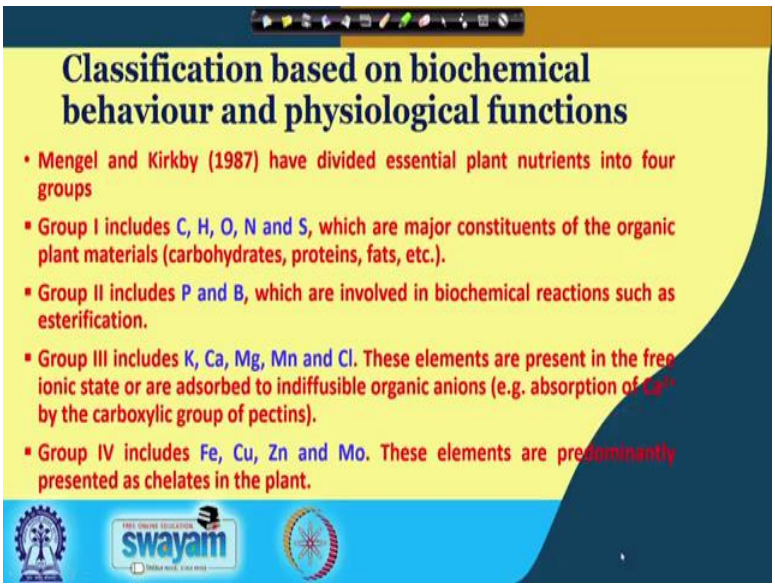

Now, how about classifying these you know these nutrients based on the biochemical behavior or physiological function. Now, Mengel and Kirkby these two scientists in 1987 has divided the essential plant nutrients into four groups.

So, let us study what are these four groups. So, the group-1 include C, H, O, N and S. These five which are the major constituents of organic plant materials like carbohydrate, like proteins, fats, etcetera. And group-2 minerals are phosphorous and boron, which are involved in biochemical reactions such as esterification. Third one third group basically contains potassium, calcium, magnesium, manganese, and chlorine. And these elements are present in the free ionic state or are absorbed to indiffusible organic anions that means, an absorption of calcium by carboxylic group of pectins.

And finally, group-5 elements that is iron, copper, zinc, and molybdenum, these elements are predominantly present in as chelates in the plant. So, you know about the chelates is that these are basically compound of organic matter you know these are compound of organic matter and metals. So, so we have learned about these four groups, and their physiological functions, so let us move ahead.

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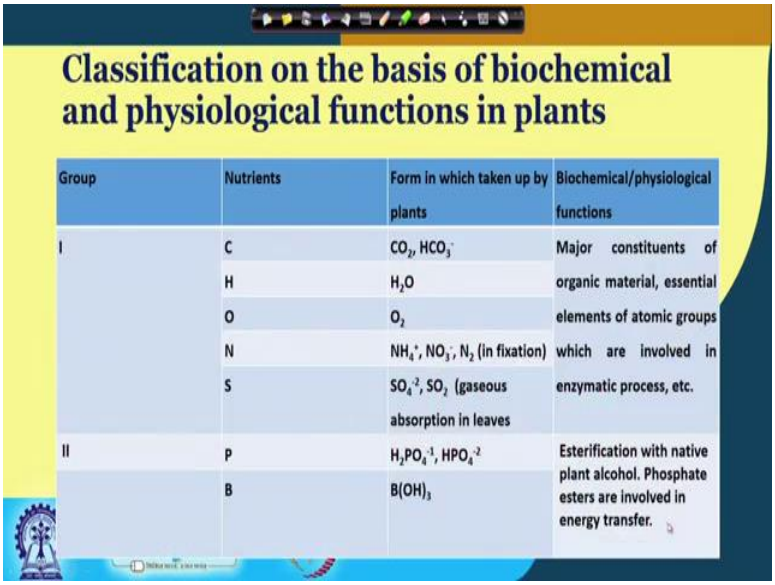

And see what are the, you know essential forms of different micro nutrients or macro nutrients, and what are their specific physiological functions. So, as we have already told that in case of group-1 obviously carbon, hydrogen, oxygen, nitrogen, and sulphur. In

case of carbon, the forms in which carbon is taken up by the plant is basically carbon dioxide, and sometime bicarbonate ion.

H is basically taken as H_2O. Oxygen by oxygen itself and nitrogen by ammonium, nitrate, and elemental nitrogen or gaseous nitrogen in case of fixation. And sulphur is obviously, in case of sulphate, and sulfur dioxide. And the sulphur dioxide basically happens, when there is a gaseous absorption in the leaves. And phosphorus is basically primary orthophosphate that is H_2PO_4 minus, and secondary orthophosphate that is HPO_4 2 minus. And boron is uptaken by $B(OH)_3$ or boric acid form or at this boron is required for esterification with native plant alcohol, and phosphate esters are involved in this energy transfer.

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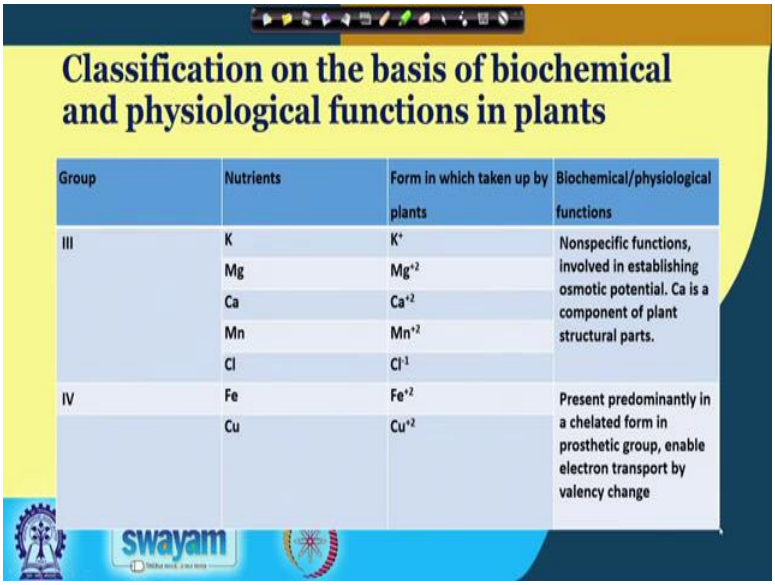

So, if you see group-3 obviously, this group-3 is a contains this 1, 2, 3, 4, 5 different nutrients. So, starting with the potassium, and forms in which potassium taken up by the plants is K plus. And magnesium is present in Mg 2 plus, calcium Ca 2 plus, manganese is Mn 2 plus, chlorine this an anion that is chloride iron that is Fe 2 plus, and copper that is Cu 2 plus.

So, these group-3 elements are having non-specific function, and basically they involves in establishing different types of osmotic potential. And calcium is a complete component of plant structural parts. So, you know plant cell structure is basically depends on the calcium content. And these iron and copper are presently present

predominantly in the chelated form in prosthetic groups, enable electron on transport by valency charge. So, each of them has their own biochemical and physiological functions.

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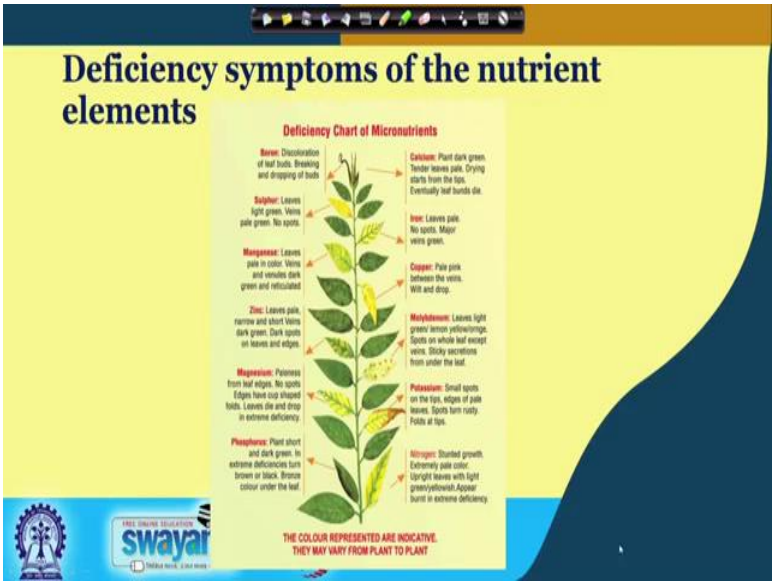

So, this chart is very very important, and this you know not chart, but this slide shows the deficiency symptoms of the nutrient elements. So, let us see them one by one, this is very important. So, the color we represented are you know indicative and also, they may vary from plant to plant.

So, let us see starting from the nitrogen, you can see nitrogen basically shows stunted growth. And extremely pale color in the lower leaves, and upright leaves with light green and yellowish, and appear burnt in extreme deficiency. So, this is a nitrogen deficiency symptoms. So, basically again in the absence of the nitrogen you will see the yellowing of the lower leaves.

In case of potassium, obviously small spots on the leaf tips, and edges of pale edges of pale leaves, and spots turn rusty, and fold sat tips. So, these are the deficiency symptoms of potassium. In case of molybdenum, and leaves get light green or lemon yellow orange, and spots on whole leaves except the veins, and sticky secretion from under the leaves.

In case of copper, it is pale pink between the veins, and wilt and drop basically these are the symptoms. In case of iron, leaves are pale no spots major veins are green in color.

And in case of calcium, the plant are dark green tender leaves are pale, and drying starts from the tips and eventually leaf buds die.

And in case of boron, discoloration of leaf buds and breaking and dropping of the buds is important. In case of sulphur, leaves light green, veins pale green, and no spots. In case of manganese, leaves pale in color, veins are venules dark green and reticulated. Zinc, obviously leaves pale narrow and yellow, and short veins short veins dark green, and dark spots on leaves and edges.

In case of magnesium, paleness from leaf edges, you can see paleness from leaf edges, and no spots edges. And a cup shaped fold and leaves die and drop in extreme deficiency. And phosphorous is very very important phosphorous plant short, and dark green, and in extreme deficiency turn brown or black, and browns color under the leaves. So, these are the you know deficiency symptoms of these individual elements.

So, guys so in this lecture, you have learnt about different types of different essential elements, and why we call them essential element, what are the essential you know essentiality criteria of these nutrient elements. And then we talked about the essential or the available forms of different nutrients. Remember that the total amount of any particular element does not mean that the total amount is available to the plant, and availability to the plant depends on the available forms.

For example, in case nitrogen it is and nitrate and ammonium. In case of phosphorous, it is primary orthophosphate and secondary orthophosphate. And in case of potassium, it is k plus. So, again nitrogen phosphate phosphorous and potassium are the macro elements, and they are present in most of the commercial fertilizers. And these commercial fertilizers you know supply these elements to the supplement this element to the deficient soil for plant growth.

And micro nutrients are also very very important, especially in India you know certain micro nutrients are deficient in certain zones, and these micro nutrients also causes also cause a lot of yield reduction. So, regardless of their quantity required, we should be very very careful about the micro nutrient status of the soil. And we have already also discussed the different deficiency symptoms of the nutrient elements.

So, plant shows different signs of the deficiency, and by identifying the proper deficiency symptom, you can identify what is the particular nutrient which is lacking in the soil. So, guys I hope that you have enjoyed this lecture, and you have learned something new. And from the next lecture onwards, we will be starting you know we will be starting nitrogen and their different transformation of the nitrogen.

Thank you very much.