Soil Fertility and Fertilizers
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Lecture 20
Soil Secondary Nutrients and Their Role in Plant Nutrition (Contd.)

Welcome friends to this last lecture of week 4 and this is the 20th lecture of week 4 of NPTEL online certification course of Soil Fertility and Fertilizers and in this week 4, we are talking about Soil Secondary Nutrients and Their Role in Plant Nutrition. So, in the previous four lectures of this week, we have discussed three secondary nutrients in the soil like calcium, magnesium and sulfur. So, we have also discussed their roles for plant growth and metabolism and also we have seen their sources.

We have described the sulphur cycle, calcium cycle and magnesium cycle. We have seen, in case of calcium and magnesium, we have seen their different types of sources like primary minerals and also how they are attached to different types of secondary minerals in the exchangeable form as well as in the intel and as well as in the layered structures, within the layer structures, specifically, for magnesium in the octahedral coordination we have discussed.

We have also seen that how these different solid phases of these three secondary nutrients remain in equilibrium with the soil solution from where these ions are up taken by plant roots. We have seen their available forms. In case of sulphur, they are available in the form of sulfate, in case of calcium they are available as calcium two plus ion and also in case of magnesium they are available as magnesium two plus ion.

Sulfur is highly correlated with biological properties because it is a constituent, it is an important constituent of several amino acids and these amino acids create different types of proteins for building the plant body. In case of calcium, we have seen that they are indispensable for plant growth because they take part in cell wall formation as well as cell division.

And in case of magnesium, magnesium governs the chlorophyll synthesis because it is an important component, structural component of chlorophyll. And without the chlorophyll plant cannot execute photosynthesis. So, these three elements although, they are required in less quantity, lesser quantity than primary minerals like calcium, like nitrogen phosphorous and potassium, they are also indispensable.

So, we have seen also their different types of sources calcium fertilizers, magnesium fertilizers as well as sulphur fertilizers we have seen. So, also we have discussed what are the factors like pH organic matter and other soil factors which affect the availability of these three secondary nutrients to the plants.

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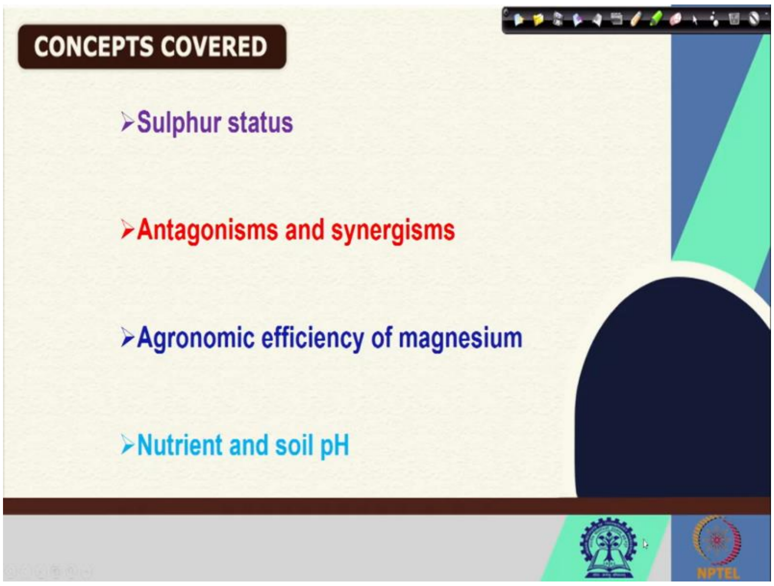

So, in this last lecture, we are going to cover this four major concepts. First of all, we are going to discuss the sulphur status of Indian subcontinent, specifically in India and also antagonism, nutrient antagonism and nutrient synergism. We are also going to discuss agronomic efficiency of magnesium and also what is the relationship between these nutrients and soil Ph. We are going to cover these four important concepts.

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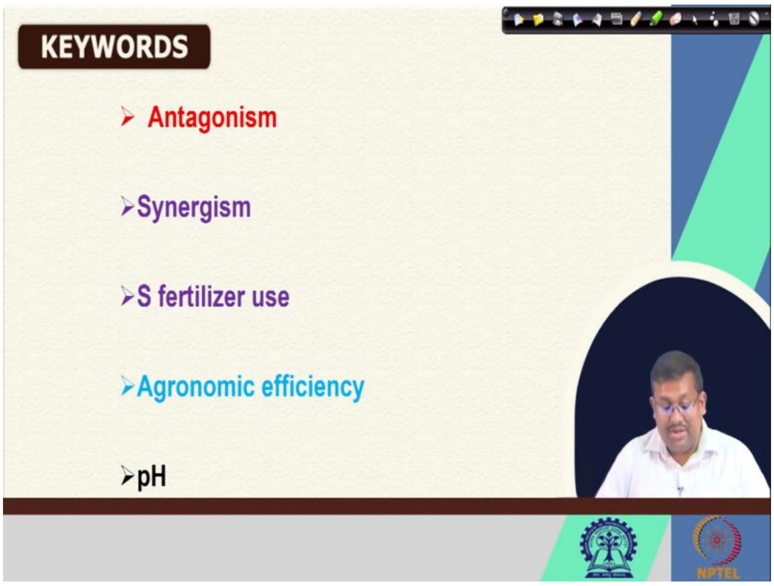

These are some of the keywords which you are going to discuss. First of all antagonism then synergism then sulphur fertilizer use agronomic efficiency and pH. So, these are some of the keywords which we are going to discuss in this lecture.

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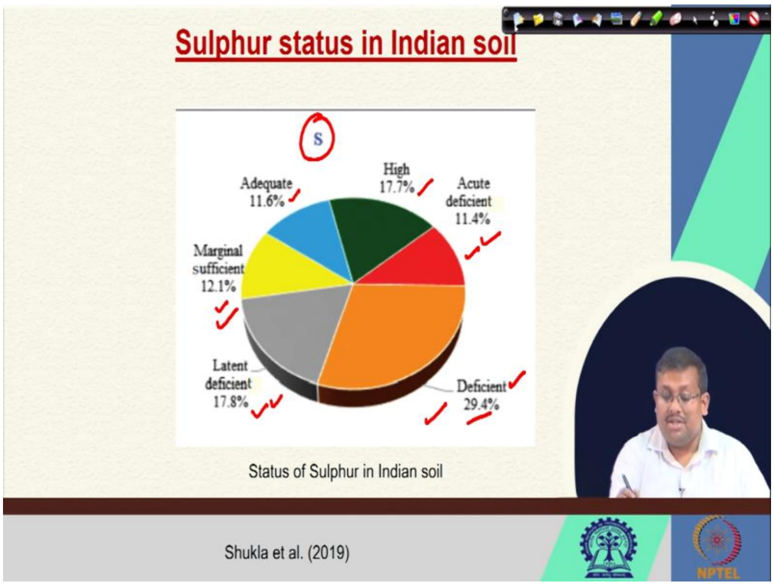

So, if we see, the sulphur status of Indian soil as published by Shukla et. al. in 2019, we can see this pie chart and in this pie chart it is quite clear that almost 29.4 percent of the Indian soils are deficient with sulfur and latent deficient is 17.8 percent of the soil marginal sufficient is 12.1 percent of the soils, adequate sulphur can be found in only 11.6 percent of the soil. High in 17.7 percent of the soil and acute deficient can be found in case of 11.4 percent.

So, only we can see that around 29 to 30 percent of the sulphur is adequate or more than adequate or high concentration in the Indian soils. So, around 70 percent of the soils in India shows different levels of deficiency, starting from acute deficiency, then deficiency, latent deficiency and marginal sufficiency. So, these are, this is the status of sulphur content in Indian soil.

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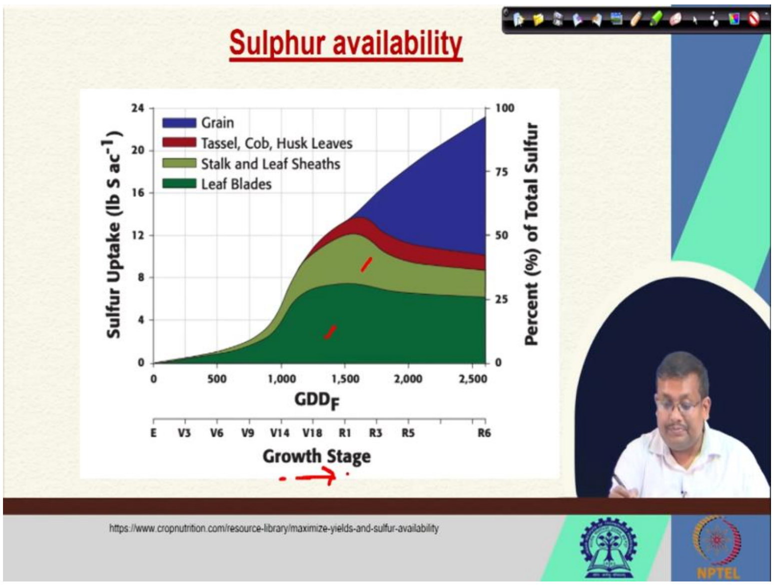

Now, if we see the sulphur uptake by different types of crops as a function of the growth stage and also if we can, if you want to see the percentage of total sulphur as a function of the growth stage, they accumulate as a function of the growth stage, we can see this graph. And we can clearly see that in case of leaf blades, the sulphur content increases and increases with an exponential rate and then reaches a plateau and goes from there.

Secondly, in case of stalk and leaf sheaths, the sulphur content also increases and then slightly decreases and continue to decrease with the growth stage or growing degree days. And also we have seen in case of tassel, cob or husk leaves, the same trend we can see, however in case of grain, we can see with the increase of growth stage, we can see there is an increase in the sulphur uptake by the grain. So, that shows the importance of this secondary nutrient for plant growth as well as for their production.

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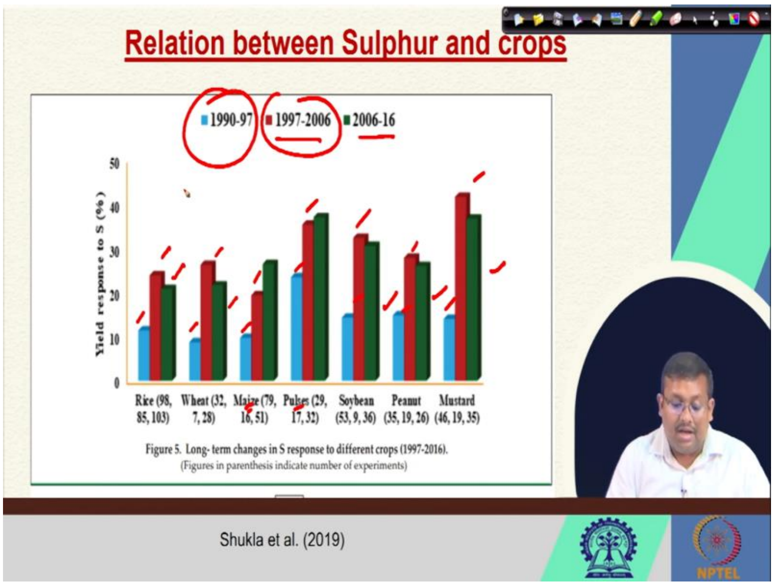

Now, if you want to see the relationship between sulphur and different crops, so, this bar diagram also gives us some idea about long-term changes in sulphur response to different crops varies from 1997 to 2016. And in this graph you can see rice, wheat, maize, pulses, soybean, peanut and mustard and the figure in the parentheses indices the number of experiments.

So, you can see that the ill response to sulphur is continuously increasing from, for all the crops, since 1990 to 97 to 1997 to 2006 and so you can see there is a, of course, there is a clear difference between the yield response to sulphur in during 1997 to 2006 as compared to 1990 to 97.

However, from 2006 to 16, except for the pulses and also maize, in all the cases like in case of rice, then wheat, then soybean and peanut and mustard, the ill response to sulphur has decreased as compared to the ill response to sulphur during 1997 to 2006. This research was published by Shukla et. al. in 2019. So, that gives us the idea about the ill response to sulphur, the temporal changes in ill response to sulphur for different crops in different, for last almost 30 years.

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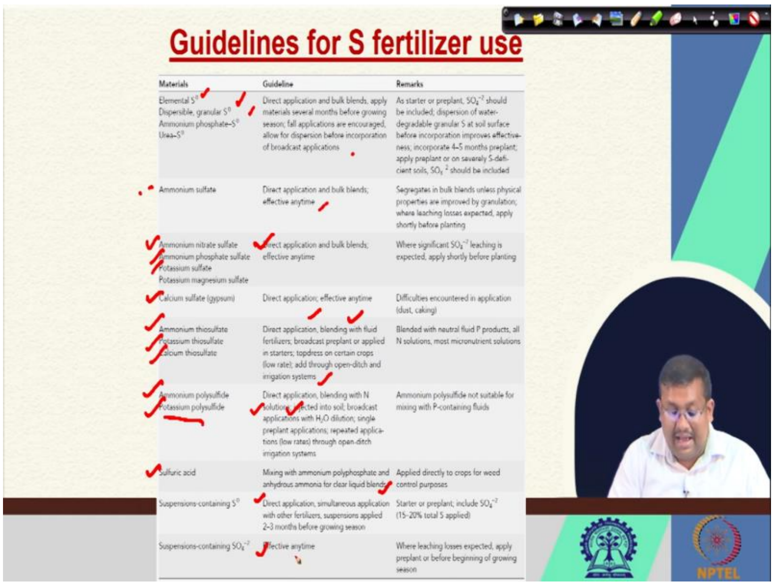

So, if we see, this is the guidelines for sulphur fertilizer use and you can see here, depending on different types of materials the guidelines and special remarks are given. So, if it is an elemental sulphur or dispersible granular Sulphur, ammonium phosphate sulfur, so, the guidelines shows that direct application and bulk blends, apply material several months before this growing season, fall applications are encouraged.

That means, in the monsoon months, this is recommended. Allow for dispersion before incorporation of broadcast applications. So, ammonium sulphate is recommended for direct application and bulk blends, effective any time. So, ammonium sulphate is effective at any time for direct application.

And then ammonium nitrate sulphate, ammonium phosphate sulphate, potassium sulphate, potassium magnesium sulphate, these are also effective for direct application and effective any time. Then calcium sulfate is helpful in for direct application and also they are effective any time. Calcium sulphate dehydrate or gypsum.

Then ammonium thiosulfate, potassium thiosulfate, calcium thiosulfate, they are also recommended for direct application and also blending with the fluid fertilizers and broadcast preplant or applied in starters, and then also topdress on certain crops, however, in the low rate. And also they are recommended to add through open-ditch and irrigation systems.

In case of ammonium polysulphide and potassium polysulphide, you can go with the direct application and blending with the nitrogen solution, we can inject it into the soil, we can broadcast with water dilution. And then single preplant application can be also possible and repeated application in low rates through open-ditch irrigation system is also possible for these two polysulphide fertilizers.

In case of sulphuric acid, mixing with ammonium polyphosphate and anhydrous ammonia for clear liquid blends is recommended. And suspension containing sulphur is, and also suspension containing sulphate are also recommended and their guidelines is given. Suspension containing sulphur is recommended for direct application and in case of suspension containing sulphate can be applicable at any time. So, these shows the proper guideline of sulphur fertilizer we use. We have already seen different types of sulphur fertilizer and their sulphur content. So, these are the guidelines for their application.

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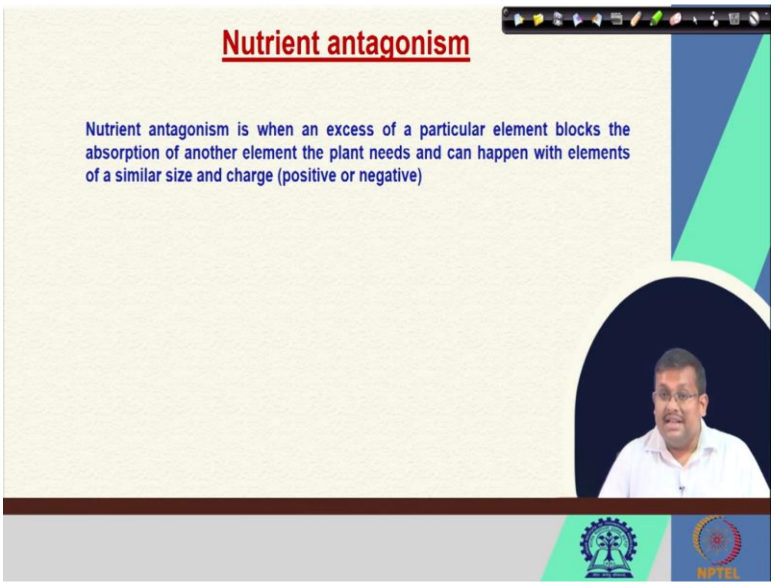

Now, another important terminology in the field of soil fertility is nutrient antagonism. What is nutrient antagonism? Nutrient antagonism is when an excess of a particular element blocks the absorption of another element, the plant needs and can happen and it can happen with any, with elements of a similar size and charge, either positive or negative. So, this is called nutrient antagonism. So, in nature or specifically in soil, we can see different types of nutrient antagonism. The opposite of this nutrient antagonism is called nutrient synergism. Also we can see synergism between several elements like nitrogen and sulphur.

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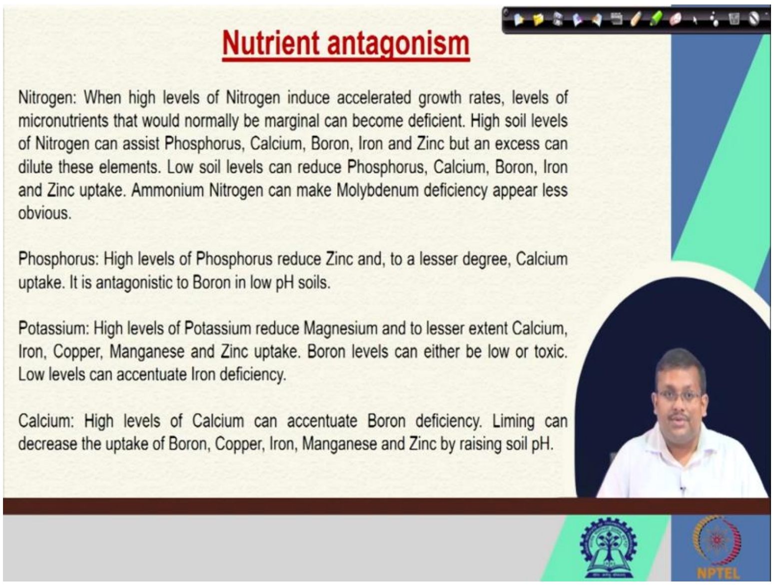

So, let us discuss element wise, what type of interactions they have with other elements. So, let us talk about nitrogen. So, when high levels of nitrogen is there that can induce accelerated growth rates, levels of micronutrient that would normally be marginal can be deficient.

So, when there is a high level of nitrogen and which can induce the vigorous growth that can sometime produce the deficiency of the micronutrients which are marginal. Now, high soil levels of nitrogen, you will see in later that high analysis fertilizers create the micro nutrient deficiency when we will discuss the micronutrients.

So, similarly, high analysis fertilizer means a fertilizer that contains more than 30 percent of the nutrient, available form of the nutrient. So, high level of nitrogenous fertilizer can induce the micronutrients deficiency because of vigorous growth. Because when there will be vigorous growth there will be more requirement.

So, when the micronutrients are marginal in the soil that would create the nutrient deficiency. So, high soil levels of nitrogen can have the synergism effect with phosphorus, calcium, boron, iron and zinc but an excess can, excess of nitrogen can dilute these elements. Low soil levels can reduce the phosphorous, calcium, boron, iron and zinc uptake and ammonium nitrogen can make molybdenum deficiency appear less obvious. So, these are some of the interactions of nitrogen with other elements.

Now, if you talk about phosphorous, high level of phosphorous reduce zinc and to a lesser degree calcium uptake. So, we can see a very clear and nutrient antagonism between phosphorus and zinc. We will see this in our discussion of micronutrients in our coming weeks.

So, there is a clear antagonistic relationship between phosphorus and zinc. It is antagonistic to boron in low pH soils also, this phosphorus. Now, for potassium. Potassium, high levels of potassium reduce magnesium, high levels of potassium reduce magnesium and to lesser extent calcium, iron, copper, manganese and zinc uptake and so, boron levels can either be low or toxic.

So, low levels can accentuate iron deficiency. So, we can see that in case of potassium, it can have antagonistic relationship with magnesium and to some lesser extent with calcium, iron, copper, manganese and zinc. Calcium, now, in case of calcium, high levels of calcium can accentuate boron deficiency.

So, liming can decrease the uptake of the boron, copper, iron, manganese and zinc by raising the soil piece. So, when we apply lime in the soil, of course, that increases the pH of the soil and when they increase the pH of the soil that decreases the availability or uptake of these nutrients like boron, copper, iron, manganese and zinc.

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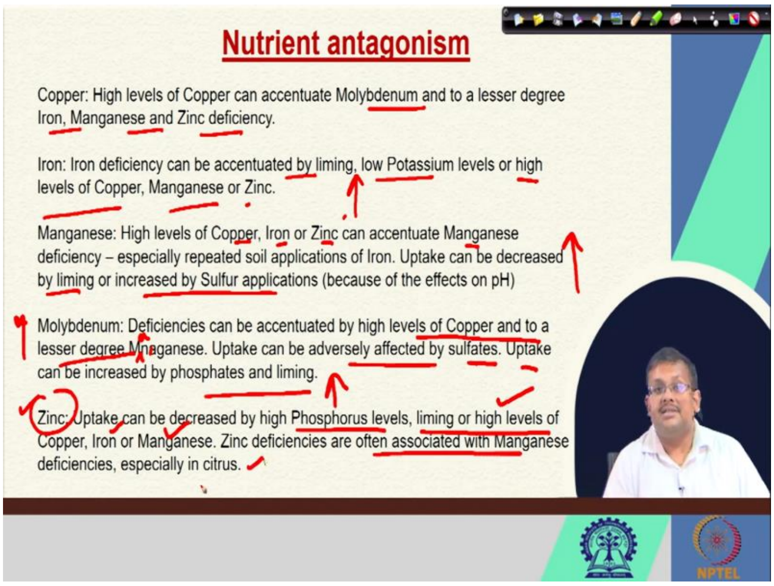

So, we can see also in case of copper, high levels of copper can accentuate molybdenum and to a lesser degree of iron, magnesium, zinc deficiency. In case of iron, iron deficiency can be accentuated by liming. Because when we apply lime that increases the soil pH and consequently there is an iron deficiency.

Also, iron deficiency can be accentuated by low potassium levels or high levels of copper, manganese and zinc. In case of manganese, high level of copper, high levels of copper, iron or zinc can accentuate manganese deficiency. So, we can clearly see the antagonistic relationship between copper, iron, zinc and manganese, especially, when repeated soil applications of iron is there.

Uptake can be decreased by liming because when we increase the soil pH that decrease the manganese availability or increased by sulphur application because their effect on the pH. So, molybdenum, deficiencies can be accentuated by high levels of copper and to a lesser degree of manganese.

Now, uptake can be, this should be manganese. So, lesser degree of manganese uptake can be also adversely affected by sulphates. Uptake can be increased by phosphates and liming. So, when we apply phosphates and liming that can improve the molybdenum availability in the plant or uptake of molybdenum into the plant.

Zinc uptake can be decreased by high phosphorus level. We have already discussed there is a clear antagonistic relationship between phosphorous and zinc. And liming of high levels of copper and liming or high levels of copper, iron and manganese, so, we can see that zinc also have antagonistic relationship with liming or high levels of copper, iron and manganese.

Zinc deficiencies are often associated with manganese deficiencies, especially, in citrus. So, we can see that there, these nutrient antagonisms are very complex relationship between these elements and one element can be present in antagonistic relationship with one or more elements or the same time that particular element can be present, can show than synergistic relationship for other elements.

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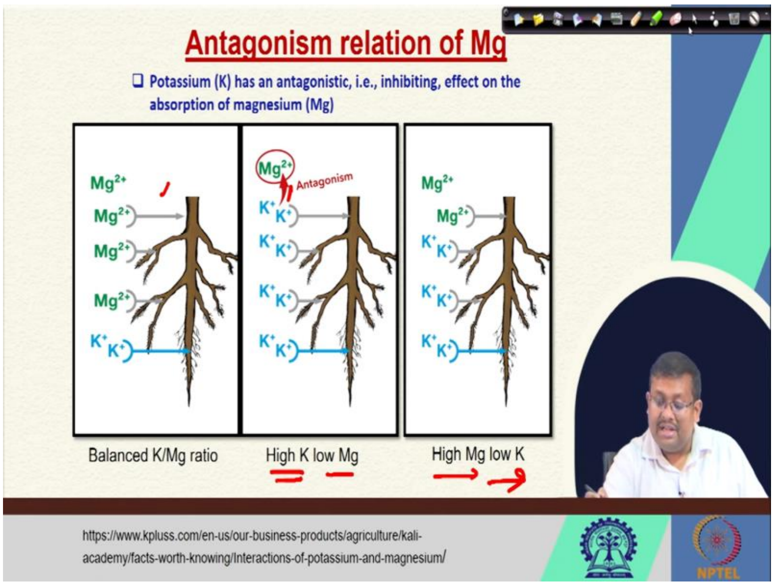

So, if we see the antagonistic relationship between potassium and magnesium, they it can be easily seen here. So, potassium has an antagonistic or inhibiting effect on the absorption of magnesium. So, this is the way there is a balanced potassium magnesium ratio is there. So, you can see roots are absorbing both.

However, when there is a high potassium and low, high potassium that would decrease the magnesium uptake. So, you can see clearly there is an antagonistic relationship. And also the opposite is also true, when there is a high magnesium and low cal, that would also decrease the potassium absorption also. So, there is a clear antagonistic relationship between magnesium and potassium.

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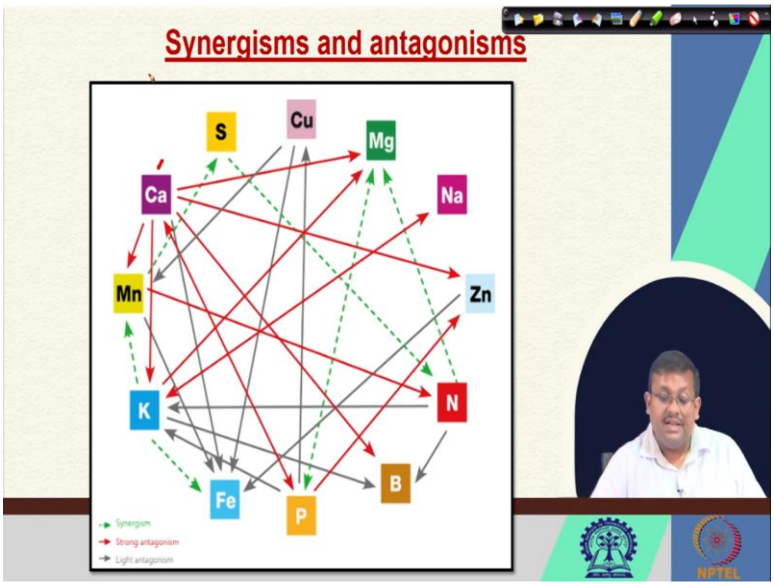

So, this pictorial description gives a bit better idea about the synergism, strong antagonism and light antagonism between different types of plant essential elements. So, we can see, calcium has antagonistic relationship with magnesium, potassium and then we they have the antagonistic relationship with phosphorus, then boron, then zinc, then magnesium.

We can also see magnesium has synergistic relationship with Sulphur, potassium has synergistic, sorry, manganese has synergistic relationship with Sulphur, potassium has synergistic relationship with both manganese as well as iron, whereas phosphorus has antagonistic relationship with zinc, magnesium has a synergistic relationship with phosphorous.

And also nitrogen has synergistic relationship with magnesium, synergistic relationship with sulphur and light antagonism with potassium and also boron. So, this gives us a very clear idea about which nutrients, the relationship between different types of nutrients in terms of synergism and antagonism.

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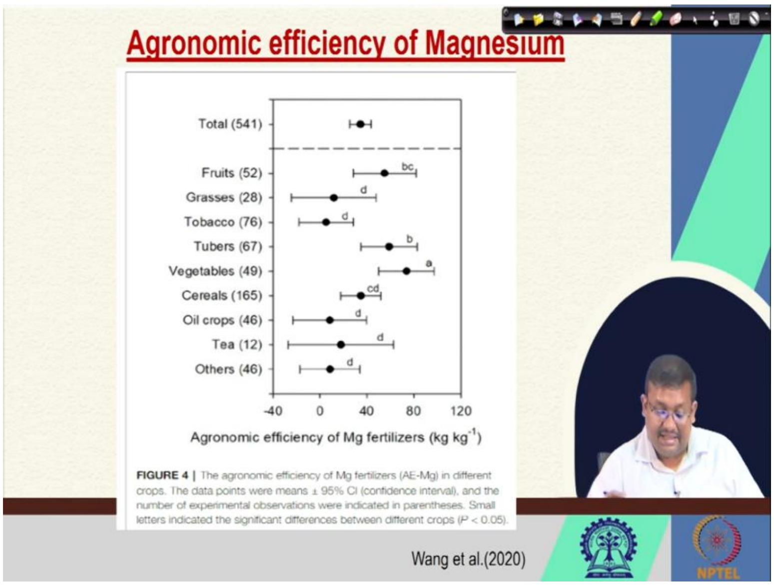

Now, if we see the agronomic efficiency of magnesium, it is actually published paper by Wang et. al. in 2020, so, where we can see that agronomic efficiency of magnesium fertilizer in different crops. So, we can see that in case of fruit crops, it varies from; the agronomic efficiency varies from around 40 to 80 kg per hectare, in case of grasses, in case of tobacco they are generally from around they are from minus 20 to plus 40.

And also we can see these variations are also there in case of tea and other crops and also for oil crops, we can see this large variation from both negative to positive agronomic efficiency of magnesium fertilizers. So, here, these data points where means of plus minus 95 percent confidence interval we can see and the number of experimental observation were indicated in this parentheses.

For example, increase the fruit, there are 52 observation, in case of grasses there are 28 observations and small letters indicated, so, this small letter generally indicated the significant difference between different crops. So, that shows the agronomic, how this agronomic efficiency of magnesium fertilizer varies between different crops and some of them are statistically significant also.

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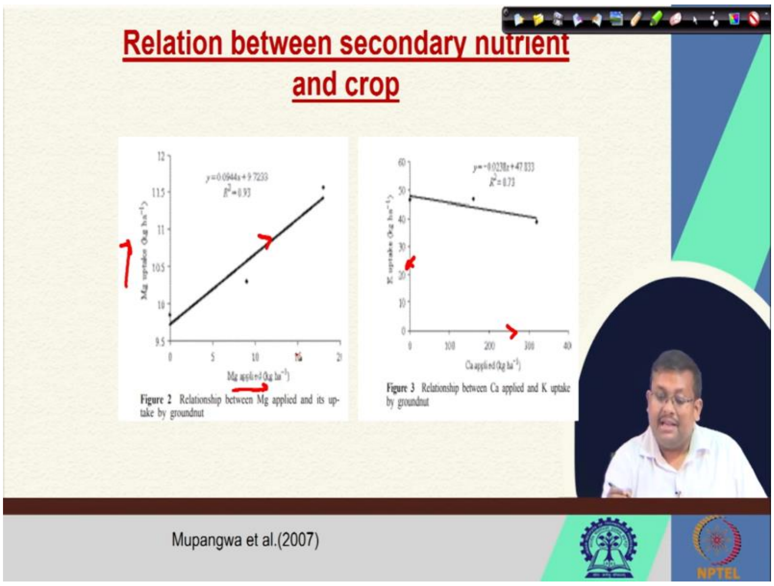

So, if you see, also the relationship between secondary nutrient and crop, this graph is showing the, in x axis it is showing magnesium applied in kg per hectare and magnesium uptake also in kg per hectare. So, we can see a straight-line relationship, positive relationship between magnesium uptake with the magnesium application.

However, we can see here, the calcium applied, when we are applying the calcium the potassium uptake is decreasing. So, this shows the relationship between calcium applied and potassium uptake by groundnut. So, these shows different types of specifically, this second plot shows the relationship between two different nutrients in any groundnut crop.

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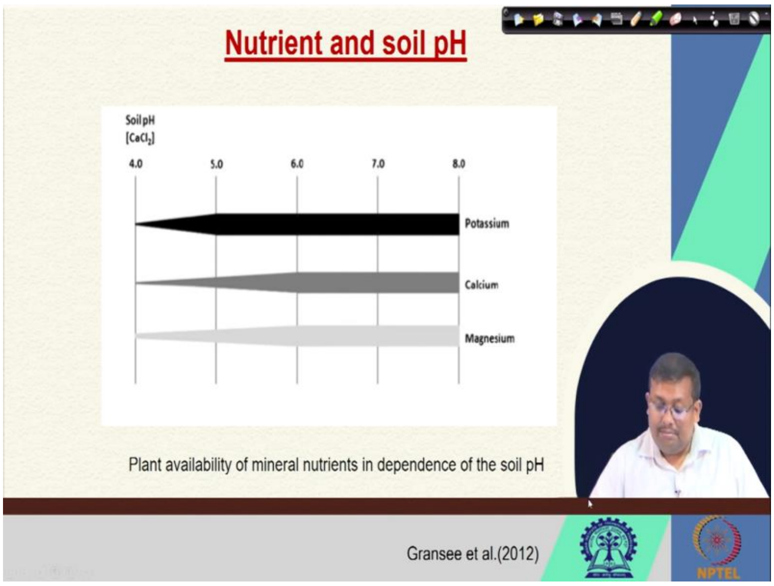

Also, the nutrient and soil pH, you can see here, the plant availability of mineral nutrient depends on the soil pH. We have already discussed that. But you can see here, the potassium availability as well as calcium and magnesium availability increases with increasing the pH from 4 to 8. So, that shows that in the low pH condition, these three minerals may not be sufficiently present for crop uptake.

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So, this makes the end of this lecture as well as this week 4 for secondary nutrients. So, we have discussed different types of secondary nutrients, three different nutrients and also we have seen their sources, their role, their cycle as well as their interaction and also their fertilizer sources and their application guidelines.

So, I hope that you have gathered some good knowledge of secondary nutrients for plant nutrition. And let us meet in our next week of lectures where we will discuss the micronutrients and their importance for plant growth. Thank you.