

Soil Fertility and Fertilizers
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Lecture 18

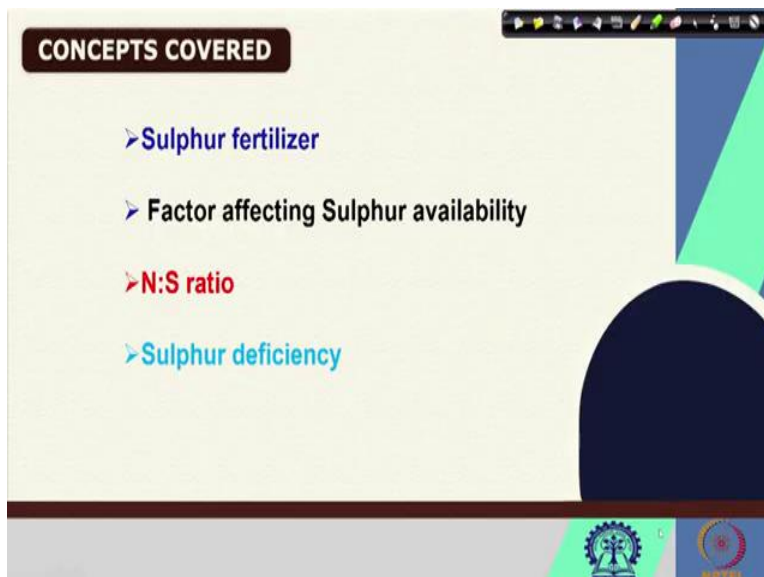
Soil Secondary Nutrients and Their Role in Plant Nutrition (Cont.)

Welcome friends to this lecture number 18 of NPTEL Online Certification Course of Soil Fertility and Fertilizers. And we are at week 4 where we are discussing Soil Secondary Nutrients and Their Role in Plant Nutrition. In our past lecture 16 and 17 we have discussed about the calcium and we have also started discussing about sulphur.

In the lecture 16 we have discussed about calcium and importance of calcium for plant nutrition, what are the different calcium sources and also what are the calcium deficiencies in the plants like blossom end rot, then cork spot, we have also discussed. In our previous lecture we have started discussing about sulphur and sulphur is also very important secondary nutrient.

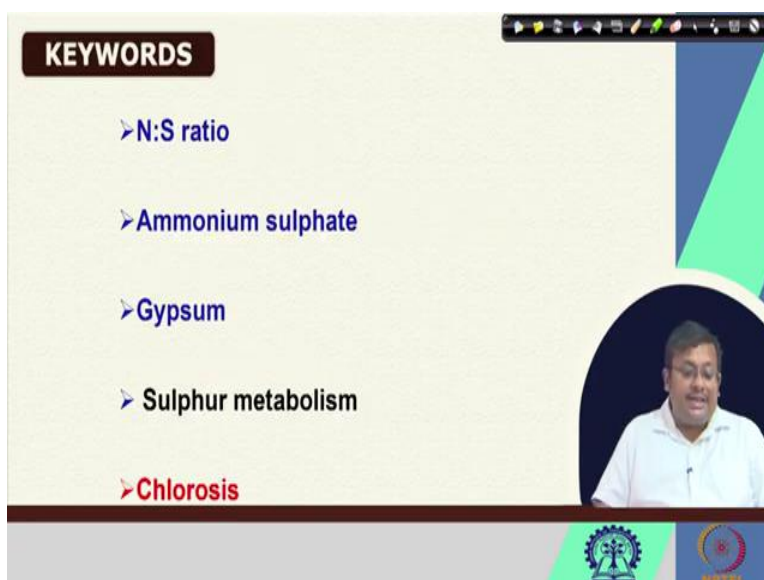
And it is required for the protein synthesis because it is a component of different essential amino acids like cysteine, cystine and methionine. So these sulphur compounds, organic compounds are essential for the growth and growth of the plants. Now sulphur is available to the plants in the form of sulphate, which is SO_4^{2-} and we have also seen different types of sources of sulphur minerals like we have discussed about pyrites. We have discussed about galena and so on. So today in this lecture we are going to start from there.

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And these are the concepts which we are going to cover in this lecture. First of all, sulphur fertilizer, their factors affecting sulphur availability and also nitrogen to sulphur ratio and also what are the deficiency symptoms of sulphur.

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So these are the keywords for this lecture like NS ratio, ammonium sulphate, then gypsum, then sulphur metabolism, chlorosis, these are some of the important keywords which we are going to discuss in this lecture.

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Fertilizer	S %
Sources of sulphate SO_4^{2-}	
Nitrate Sulphate	5-14
Ammonium sulphate	24
Simple superphosphate	12
Ammonium sulphate-phosphate	14-20
Calcium sulphate	14-18
Potassium sulphate	16-22
Calcium-Magnesium sulphate	22
Magnesium sulphate (Epsom)	18
Magnesium sulphate (Kiesirite)	22
Sources of elemental sulphur	
Elemental sulphur	85-100
Triple superphosphate granulated with sulphur	18
Sulphur Bentonite	85-90

Now let us see first what are the important sulphur fertilizers. So these are some of the important sulphur fertilizers like nitrate sulphate, which contains 5 to 14 percent of sulphur, then ammonium sulphate, which is the major sulphur fertilizer which contains 24 percent of sulphur, then simple superphosphate contains 12 percent of sulphur, then ammonium sulphate phosphate contains 14 to 20 percent of sulphur.

Calcium sulphate contains 14 to 18 percent of sulphur. Potassium sulphate contains 16 to 22 of sulphur. Calcium magnesium sulphate contains 22 percent of sulphur. Magnesium contains 18 percent of sulphur and magnesium sulfate, which is also known as kieserite, so there are two types of magnesium sulphate salts, one is Epsom salts, which contain 18 percent, another is magnesium sulfate which is kieserite contains 22 percent of sulphur.

And so there are different types of sources for elemental sulphur. First of all, the elemental sulphur contains 85 to 100 percent of sulphur. Triple superphosphate granulated with sulphur will contain 18 percent sulphur and sulphur bentonite contains 85 to 90 percent of sulphur. So these are some of the sulphur sources which we can apply as fertilizer to correct the sulphur deficiency.

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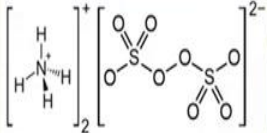

Sulphur fertilizer

Ammonium Sulphate

- N-21%
- S-24%
- Water solubility-750g/L
- Solution pH- 5 to 6

☐ 70% of global output originates from the production of caprolactam

☐ The main advantages of ammonium sulphate are low hygroscopicity and chemical stability.



Now let us first start discussing with the ammonium sulphate. So this ammonium sulphate looks like this white crystalline salt like compound, now it has 24 percent sulphur and it has water solubility of 750 grams per liter and solution pH of this ammonium sulphate can vary from pH 5 to 6. Now remember that 70 percent of this global output of this ammonium sulphate originates from the production of caprolactam.

And the main advantage of ammonium sulphate are they have low hygroscopicity and they have chemical stability also. So this is the structure of ammonium sulphate.

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Sulphur fertilizer

Ammonium Sulphate

- Formula for Ammonium Sulfate: $(\text{NH}_4)_2\text{SO}_4$
- Properties for Ammonium Sulfate
 - Molar mass: 132.14 g/mol
 - Density: 1.769 g/cm³ (20 °C)
 - Melting point: 235 to 280 °C (455 to 536 °F; 508 to 553 K) (decomposes)

And so the formula of ammonium sulphate is NH_4 whole 2SO_4 . Properties we can see here molar mass of 132.14 gram per mole, density is 1.769 gram per cc at 20 degree centigrade and melting point of this ammonium sulphate varies from 235 to 280 degree centigrade. And so which is equivalent to 455 to 536 degree Fahrenheit and 508 to 553 Kelvin.

So these are some of the characteristics of ammonium sulphate. So ammonium sulphate is a salt like compound you can, this is what ammonium sulphate looks like. So apart from nitrogen which contains around 20 to 21 percent it also supplies the sulphur as a secondary nutrient.

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Sulphur fertilizer

Single Superphosphate

- S-11 to 12%
- SSP is also known as ordinary superphosphate and normal superphosphate.
- It is composed of **50% by weight** each of monocalcium phosphate and gypsum or its lower hydrate.

Ammonium Phosphate Sulphate

- It is composed of about **40%** monoammonium phosphate and **60%** ammonium sulphate.
- The most common grade of ammonium phosphate sulphate is **16-20-0-14S**
- It is made up of reacting a mixture of phosphoric acid and sulphuric acid with ammonia and introducing ammonium sulphate solutions and H_2SO_4 into a H_3PO_4 plant reaction circuit.

So single superphosphate it contains 11 to 12 percent of sulphur and single superphosphate is also known as ordinary superphosphate or normal superphosphate or simple superphosphate. So it is composed of 50 percent by weight of monocalcium phosphate as well as gypsum or its lower hydrate. So this thing single superphosphate is also another phosphatic fert... another fertilizer which contain this secondary sulphur.

Another sulphur source is ammonium phosphate sulphate, which is composed of 40 percent monoammonium phosphate and 60 percent ammonium sulphate. The most common grade of ammonium phosphate sulphate is given there that is 16-20-0-14 percent sulphur and it is made of reacting a mixture of phosphoric acid and sulphuric acid with ammonia and introducing ammonium sulphate solution and sulphuric acid into a phosphoric acid plant reaction circuit. So this ammonium phosphate sulphate is another sulphur fertilizer.

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Sulphur fertilizer

Potassium Sulphate

- S-16 TO 22 %
- About 25% of world K_2SO_4 capacity is based on the reaction between potassium chloride and H_2SO_4



Gypsum (Calcium Sulphate)

- S-14 to 18 %
- Gypsum byproduct comes from fossil-fuel power stations where S is scrubbed from exhaust gas
- It is also called as land plaster
- Improves acid soils and treats aluminum toxicity.
- Improves water infiltration and soil structure.



Sulphur fertilizer

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katyayan (2012)

Potassium sulphate - Now potassium sulphate generally it varies from sulphur contents varies from 16 to 22 percent. So we have already discussed here in the potassium sulphate that is 16 to 22 percent, so again here we can see that the potassium sulphate sulphur content varies from 16 to 22 percent. About 25 percent of the world potassium sulphate capacity is based on the reaction between potassium chloride and H_2SO_4 .

So when there is a reaction between potassium chloride and sulphuric acid that will create this potassium sulphate. Gypsum which is calcium sulphate dehydrate, so this is another important

sulphur source. So in case of gypsum it contains 14 to 18 percent of sulphur. So gypsum by product comes from different fossil fuel power station where sulphur is scrubbed from exhaust gases. It is also called the land plaster.

So generally gypsum is used for plastering purposes, so also known as plaster of Paris. Improves, when we apply this gypsum it improves acid soils and treats aluminum toxicity and improves the water infiltration and soil structure. However, gypsum is mainly applied for correcting the alkalinity of the soil.

So what happens when we apply the gypsum into the soil that the calcium from the gypsum replaces the sodium from the alkaline soil and thereby, improves the physical condition of the soil. So to reduce the alkalinity of the soil we generally apply gypsum. Gypsum is another important source of sulphur, which contains 14 to 18 percent of sulphur.

So if we see the whatever sources which we have discussed, we have already discussed this ammonium sulphate, we have discussed, sorry, we have discussed this ammonium sulphate, we have discussed this single or simple superphosphate, we have also discussed this ammonium sulphate phosphate and then we have discussed this potassium sulphate. So these are some of the major sulphur fertilizers which we apply for correcting the sulphur deficiency in crop plants.

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Factors affecting Sulphur availability

- Type and amount of clay**
 - Higher amount of clay decreases Sulphur availability
- pH**
 - The amount of released Sulphur is directly proportional to soil pH up to 7.5
- Organic matter**
 - Soil containing higher organic matter have higher amount of Sulphur supply to soil

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Let us now discuss what are the factors which affect the sulphur availability in the soil. First important factor is type and amount of clay. So higher amount of clay decreases the sulphur availability. Secondly the pH, pH is the amount of released sulphur is directly proportional to soil pH up to pH 7.5. Third is organic matter, as we know that sulphur is an important component of several essential amino acids or proteins.

So of course, the higher organic matter implies higher sulphur supplying capacity in the soil, so higher organic matter facilitates the sulphur supply to soil.

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Factors affecting Sulphur availability

- Salt content**
 - Accumulation of Sulphur favored in soil of high salt content like coastal saline and alkaline soils
- Cation and Anions**
 - Acid soils containing higher amount of H^+ retain a greater amount of sulphate Sulphur
- Presence or absence of vegetation**
 - A greater amount of Sulphur is mineralized in cropped than that of uncropped soils

Salt content is another important factor because accumulation of sulphur favored in soils of high salt content like coastal saline and alkaline soil. So wherever there are saline soils that will help in accumulation of sulphur compounds. Cations and anions are also important factors. Acid soil containing higher amount of proton retain a greater amount of sulphate sulphur.

Presence or absence of vegetation - A greater amount of sulphur is mineralized in the cropped soil as compared to the uncropped soil. So the salt contain cations and anions and presence or absence of vegetation all these are important factors which governs the sulphur availability to the crop.

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Factors affecting Sulphur availability

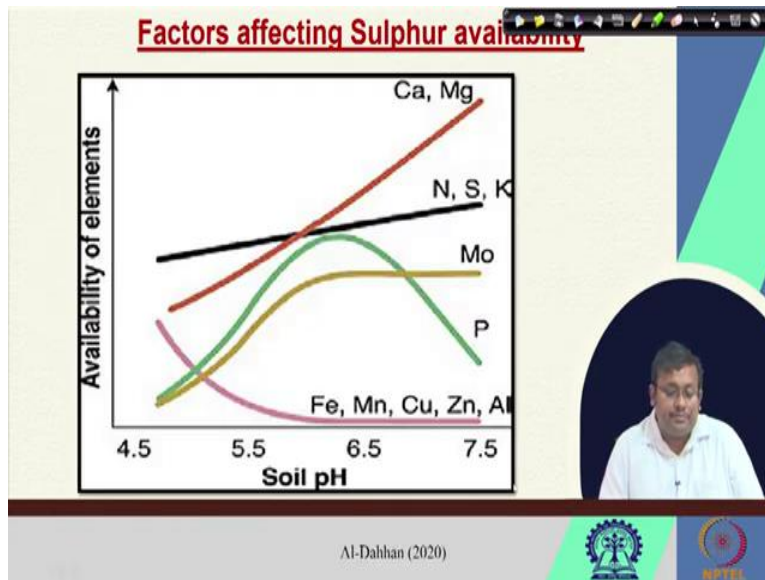
- ❑ Alternate wetting and drying
- ❑ Drying after soil saturation reduce the Sulphur content in the soil
- ❑ Interaction of Sulphur with other nutrients
- ❑ The application of Zn increased the utilization of Sulphur by crops
- ❑ The interaction of N with S found to be synergistic
- ❑ A similar positive interaction has found between S and P

Another important factor is alternate wetting and drying. So drying after soil saturation can reduce the sulphur content in the soil. So that is also important factor. And finally interaction of sulphur with other nutrients are also important for controlling the sulphur availability to the plant. So the application of zinc increased the utilization of sulphur by the crops and the interaction of nitrogen and sulphur found to be synergistic in nature.

So of course, this nitrogen and sulphur are synergistic because they perform almost some similar functions within the plant body. So a similar positive interaction has found between sulphur and phosphorus. So we can see some similarity between nitrogen and sulphur and also interestingly there are some similarity between nitrogen and sulphur deficiency symptoms.

Although there are some stark differences we are going to discuss this in this upcoming slide, but remember there is some confusions of, there may be some confusion regarding the nitrogen as well as sulphur deficiency symptoms in the plants and there are certain ways to detect those, we are going to discuss those.

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So if we see the availability of the elements at different soil pH we can see that although with the increase of soil pH, the availability of iron, manganese, copper, zinc and aluminum decreases, but the availability of molybdenum, calcium, magnesium and nitrogen sulphur and potassium increases. So the temp, the raising the soil pH up to 7.5 will have the beneficial effect to the availability of sulphur.

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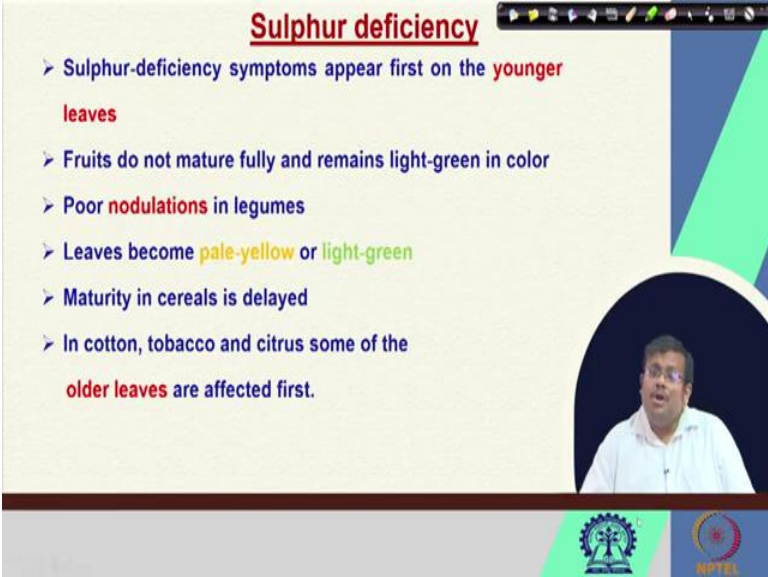
N:S ratio

- Sulphur metabolism in plants is closely linked with Nitrogen as both are constituents of protein
- N: S ratio of **15-16:1** for legumes
- N: S ratio of **11-12:1** for cereals
- N: S ration of **10:1** in fertilizer meets the S requirement
- In the absence of S in soils, utilization of NO_3^- can be hampered

So NS, let us discuss then NS ratio. So sulphur metabolism in plant is closely linked with nitrogen as both the constituents are; as both nitrogen and sulphur are constituents of protein, so NS ratios generally vary from 15 to 16 is to 1 for legume. For cereals is vary from 11 to 12 is to 1 and so basically you can see here nitrogen is greater in legumes, of course.

And NS ratio of 10 is to 1 in fertilizer can meet the sulphur requirement of the crops. So in the absence of sulphur in the soil utilization of nitrate can be also hampered, because they have some synergistic relationship. Utilization of nitrate can also be hampered if there is sulphur deficiency in the soil.

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Sulphur deficiency

- Sulphur-deficiency symptoms appear first on the **younger leaves**
- Fruits do not mature fully and remains light-green in color
- Poor **nodulations** in legumes
- Leaves become **pale-yellow** or light-green
- Maturity in cereals is delayed
- In cotton, tobacco and citrus some of the **older leaves** are affected first.

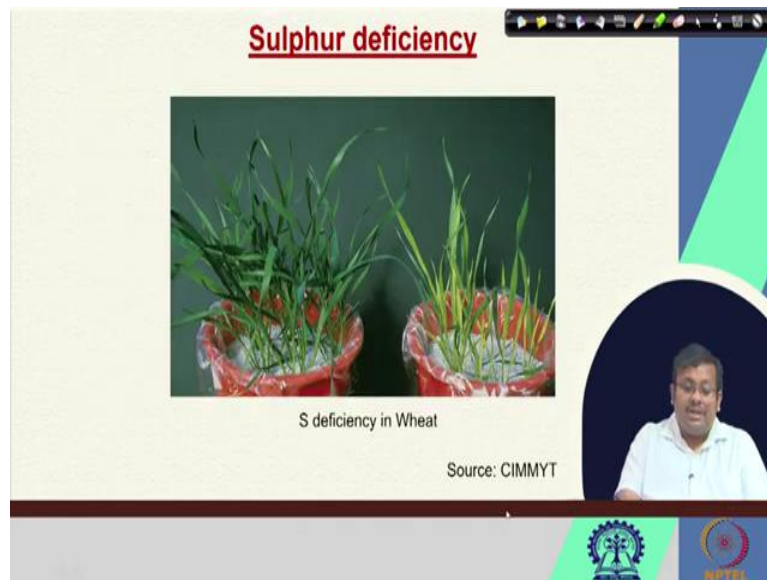
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Now what are the symptoms of sulphur deficiency? Sulphur deficiency symptoms appear first on the younger leaves. So this is the most stark difference with the nitrogen deficiency symptoms. Remember that in case of nitrogen deficiency symptoms the, since nitrogen is mobile within the plant, so nitrogen deficiency symptoms occur in the older leaves.

But in case of sulphur, sulphur is relatively immobile within the plant, so that is why sulphur deficiency occurs first in the younger leaves. Fruits also do not mature fully and remains light green in color. So this is another important feature of sulphur deficiency. Poor nodulation in legumes and leaves also become pale yellow or light green and maturity in cereal is delayed and

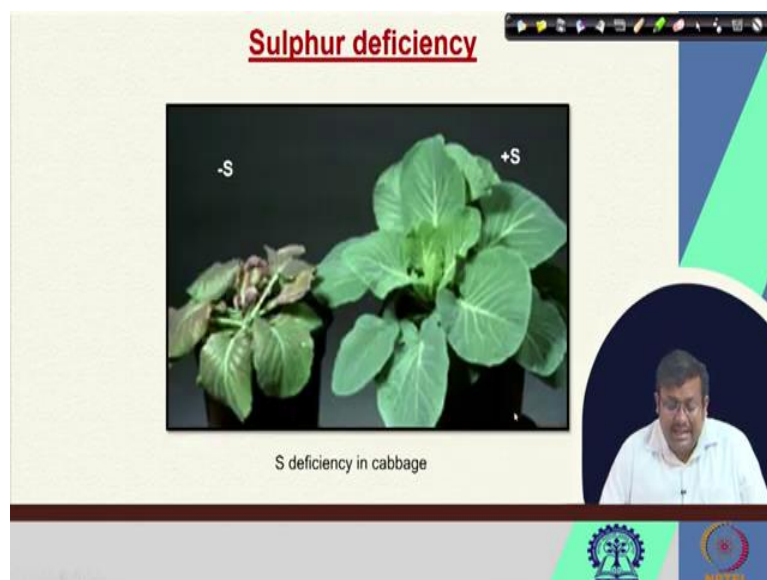
in cotton, tobacco and citrus some of the older leaves are also affected first. So we can see these are some common sulphur deficiency symptoms.

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Interveinal chlorosis is also important deficiency symptoms which we are going to discuss. So you can see here it is a sulphur deficiency, severe sulphur deficiency in wheat. So this is the normal healthy wheat plant and here you can see sulphur deficient wheat. So you can clearly see what is the importance of sulphur for the plant growth.

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Sulphur deficiency

- Sulphur-deficiency symptoms appear first on the **younger leaves**
- Fruits do not mature fully and remains light-green in color
- Poor **nodulations** in legumes
- Leaves become **pale-yellow** or **light-green**
- Maturity in cereals is delayed
- In cotton, tobacco and citrus some of the **older leaves** are affected first.




Another is picture you can see here one is with proper dose of sulphur and here you can see the sulphur deficient. So sulphur sufficient and sulphur deficient, so you can see the changes. As you can remember I have already told you that there are some color changes when there is a sulphur deficiency, so that can be easily seen here in this cabbage leaves.



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Sulphur deficiency

Chlorosis and **pale stripes** visible between the veins



S deficiency in Banana



Also we can see some interveinal chlorosis and pale strips visible between the veins, so that is why it is called interveinal chlorosis. So these are the banana leaves, so you can see interveinal chlorosis can be easily seen for sulphur deficiency.

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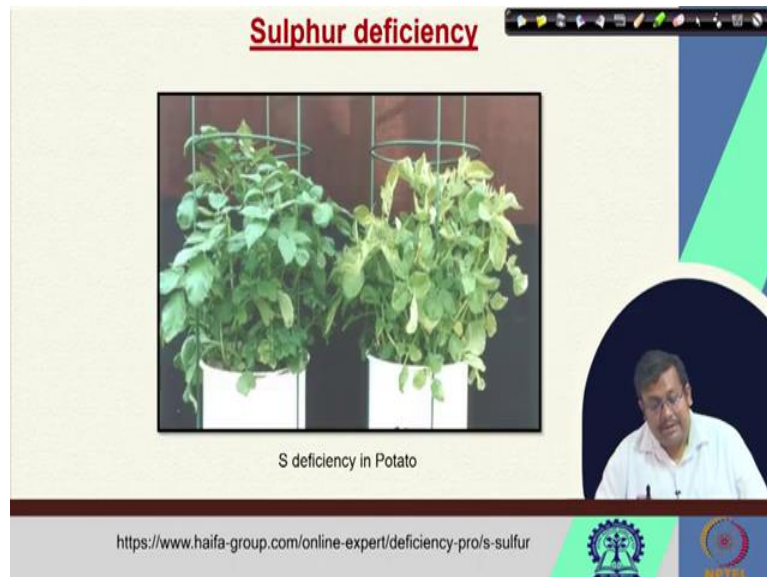
Also you can see here this is this photograph showing the sulphur deficiency in ground nut.

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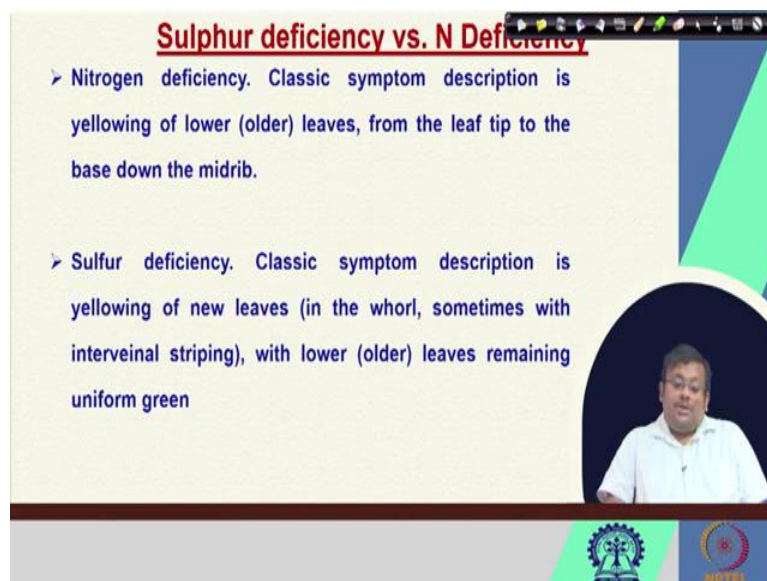
So this is showing sulphur deficiency in lettuce.

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And here you can see sulphur deficiency in potato.

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So as I told you there can be some confusion between the symptoms of sulphur deficiency and nitrogen deficiency. So you should remember two important things, one is in case of nitrogen deficiency classic symptoms description is yellowing of the lower or older leaves from the leaf tip to the base down the midrib.

So these symptoms generally occur in the older leaves first. In case of sulphur deficiency classic symptom description is yellowing of new leaves in the whorl, sometimes with the interveinal stripping. So that is what is called interveinal chlorosis, with lower leaves remaining uniform green. So since the sulphur is relatively immobile, of course, that is why the sulphur deficiency symptoms appear in the new leaves.

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Sulphur deficiency vs. N Deficiency

- Both N and S are tied together due to several common physiological process, therefore, early growth symptoms can be similar. Examples including overall leaf and plant yellowing, spindly plants, and interveinal striping. These similar symptoms most often occur when plants are small and there is severe deficiency (low soil supply and no fertilization).
- Also, plant response from fertilizer application can be quite similar for N and S, that is, good growth and green plants with uniform coloration

Now both nitrogen and sulphur are tied together due to several common physiological processes. Therefore, early growth symptoms can be similar, so I told you that both nitrogen and sulphur are important components of protein. So you can expect that they have some common physiological processes. So the early growth symptoms can be similar. Examples can be including overall leaf and plant yellowing, spindly plants and interveinal stripping.

And these similar symptoms most often occur when plants are small and there is severe deficiency, there is low soil supply and no fertilization. Also plant response from fertilizer application can be quite similar for nitrogen and sulphur that is good growth and green plants with uniform coloration. So when you apply the fertilizer in the soil both nitrogen and sulphur fertilizer will see some plant response.

So the plant response can be similar in both these cases because they have similar physiological roles in the plant body. So we can see good growth and green plants with uniform coloration.

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<https://www.haifa-group.com/online-expert/deficiency-pro/s-sulfur>

The slide includes a video inset of a man in a white shirt speaking. At the bottom, there are logos for institutions, including one with a gear and another with a globe.

So guys so that makes the end of a discussion of sulphur. So we have learned that sulphur is a very important component. It has role for growth of the plant and sulphur is an important component of cruciferous plant and sulphur is present as a structural component of different essential amino acids so they form the proteins also and they have similarity in physiological process, physiological roles as we can see in case of nitrogen.

So nitrogen and sulphur deficiency symptoms are almost same, however, in case of nitrogen deficiency symptoms occur in the older leaves because of its mobility within the plant however, in case of sulphur the deficiency symptoms occur in the newer leaves because of relative immobility within the plants.

We have also discussed different sources of sulphur and also sulphur fertilizers, we have discussed about single super phosphate, we have discussed about ammonium sulphate, we have discussed about gypsum. And so these are the common sulphur source, which we apply to correct any sulphur deficiency.

One of the major sulphur deficiency symptoms is interveinal chlorosis. So chlorosis occurs within the veins, so that is why it is known as interveinal chlorosis. So we have also discussed the sulphur cycle. So I hope that you have got, you have gathered some useful knowledges from this lecture and let us wrap up this lecture.

These are some of the references, which I have used for this for this lecture and let us meet in our next lecture to discuss the magnesium and its importance for plant metabolism. Thank you.