Soil Fertility and Fertilizers
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Lecture 09
Soil Nitrogen for Plant Nutrition

Welcome friends to this fourth lecture of week two of NPTEL online certification course of soil fertility and fertilizers. And in this week, our topic is soil nitrogen for plant nutrition. In our previous lectures of this week, we have already discussed some of the important processes of soil nitrogen and how soil nitrogen moves from soil to the atmosphere.

And also, the we have also discussed the dynamics of soil nitrogen. We have seen some and also, we have discussed some of the important soil nitrogen processes, like, ammonification, then nitrification then mineralization, nitrification, denitrification. So, in this week we are going to discuss some of the important nutrient use efficiency terms.

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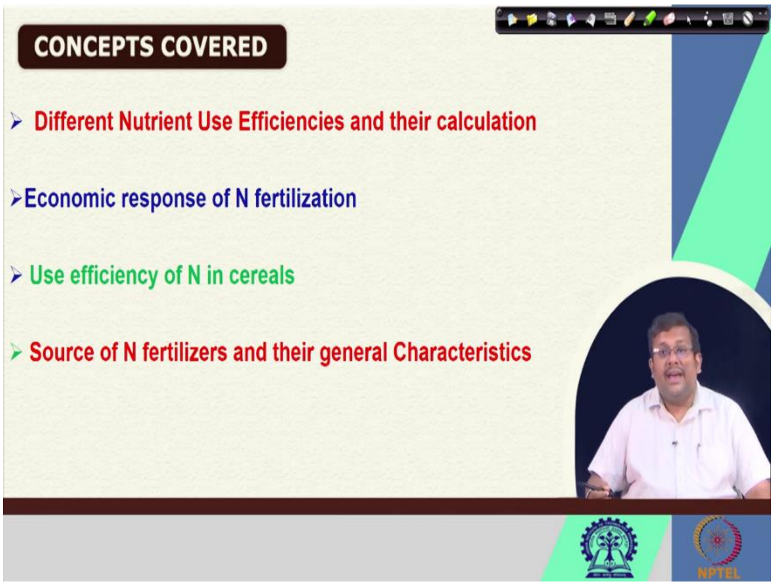

So, these are the concepts which we are going to discuss in this lecture that is different nutrient use efficiencies and then how to calculate them. Secondly, we are going to see the economic response of nitrogen fertilization and, then we are going to discuss about use efficiencies of nitrogen in cereals. And then, we are going to discuss about the source of nitrogen fertilizers or nitrogenous fertilizers and their general characteristics.

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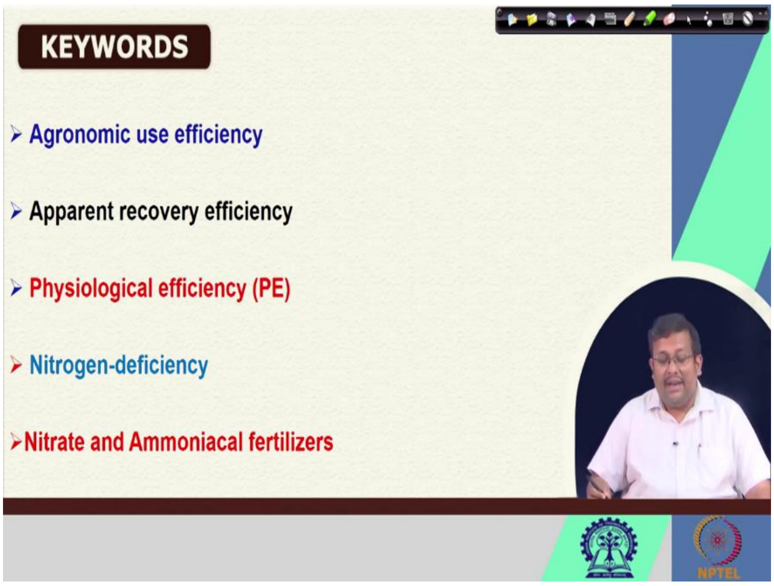

These are some of the keywords which we are going to discuss. First of all, agronomic use efficiency, apparent recovery efficiency, then physiological efficiency, nitrogen deficiency and nitrate and ammoniacal fertilizers. So, these are some of the keywords which we are going to cover in this lecture.

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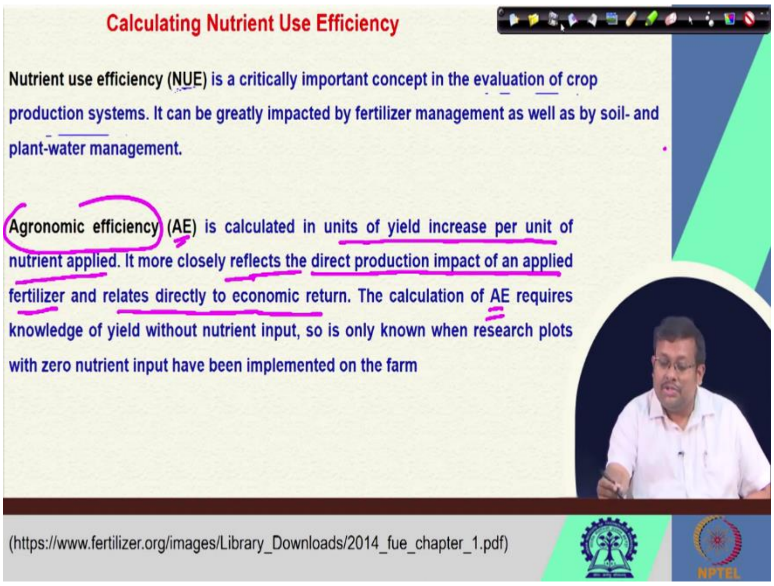

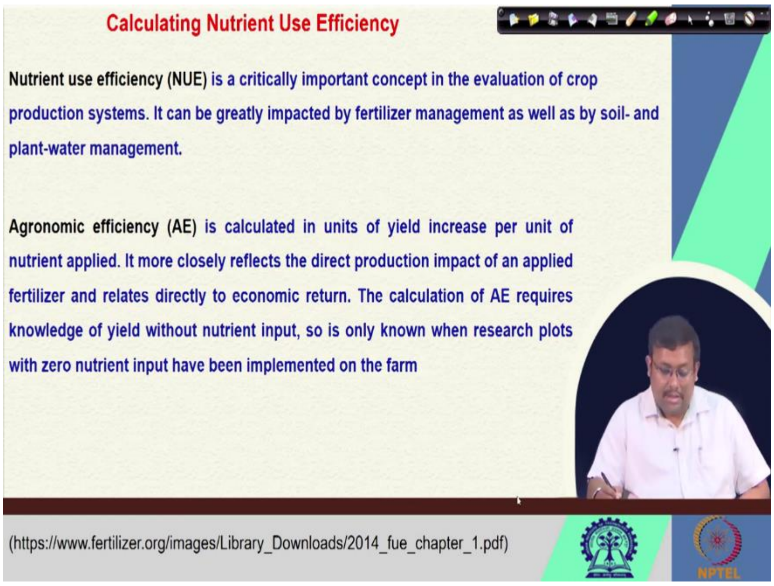

So, let us start with the nutrient use efficiency. Well, you must understand that whatever, nutrient is there in the soil, plant cannot take up all, of it. And, so only a certain percentage of that nutrient is available to the plant. And based on this recovery of those fractions of available nutrients, which are present in the soil, there are different types of terms. For example, nutrient use efficiency, agronomic use, agronomic efficiency and so on, and we are going to discuss these terms.

So, first let us discuss what is nutrient use efficiency. If you see this term that it is also, in short term, we call it NUE. So, anyway is a critically important concept in the evaluation, in the evaluation of crop production system. This is a very important term. whenever we talk about the proper fertilizer management, it is very important to understand the nutrient use efficiency.

It can be more critical for fertilizer elements like nitrogen, because nitrogen is highly dynamic in soil system. So, nutrient use efficiencies, of course a critically important concept in the evaluation of crop production system. At the same time, it can be greatly impacted by fertilizer management, as well as by soil and plant water management. Let me just increase the width and change the color.

Now the second important term is agronomic efficiency. We also denote this agronomic efficiency by this AE term. So, this AE is calculated in units of yield increase per unit of nutrient applied. So, this is called the agronomic efficiency. Now, it more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return. So, agronomic efficiency is more closely related to the direct production, as well as the economic return.

Now, the calculation of these agronomic efficiency requires knowledge of yield without nutrient input. That means in the controlled fertilizer, in control plots. So, is only known when research plots with zero nutrient inputs have been implemented on the farm. So, these are called control plots. So, only when we know the uptake from the control plot, then only we can calculate this agronomic efficiency. So, for calculating the agronomic efficiency, we declare the nutrient uptake from the control plot.

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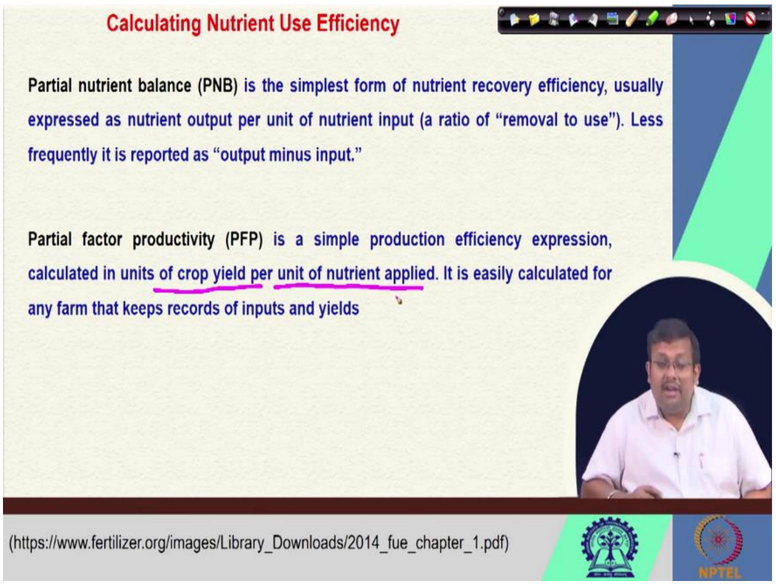

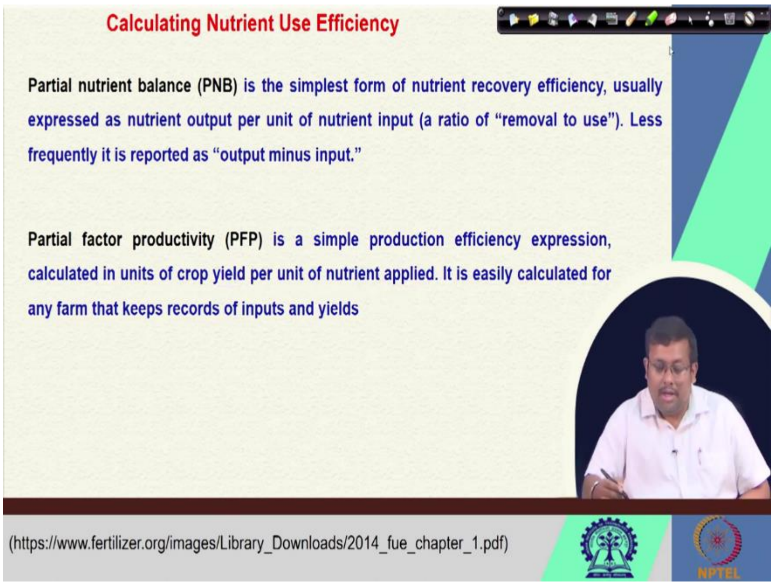

So, the third important concept is partial nutrient balance, or PNB. Now what is PNB? PNB is the simplest form of nutrient recovery efficiency, which is usually expressed as nutrient output per unit of nutrient input, which is also known as a ratio of removal to use and less frequently. It is also reported as output minus input. So, this is called partial nutrient balance. Another important term you will frequently, come across that is called partial factor productivity or PFP.

So, it is a simple production efficiency expression, and it is calculated unit of crop will per unit of nutrient applied. So, it is easily calculated for any farm that keeps that keeps records of inputs and yields. So, this is called partial factor productivity. Now we know what is nutrient used efficiency, what is agronomic efficiency? What is partial nutrient imbalance? And also, we have now, we now know what is partial factor productivity.

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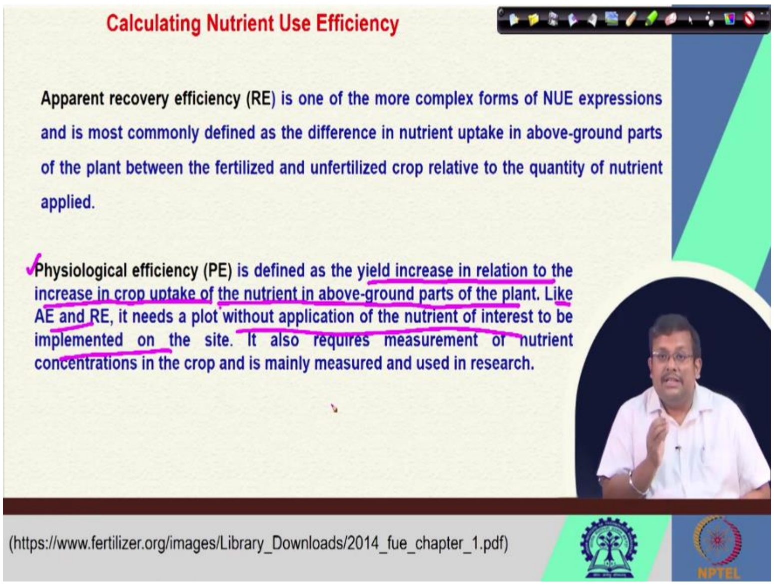

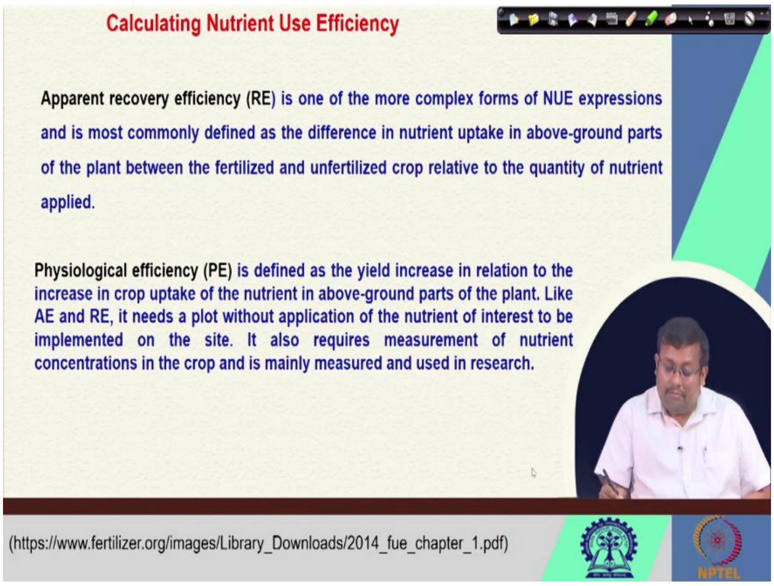

So, another important term is apparent recovery efficiency or RE. So, it is a more complex term. It is a more complex expression of nutrient use efficiency, and it is most commonly defined as the difference in nutrient uptake in above ground parts of the plant between the fertilized and unfertilized crop relative to the quantity of the nutrient applied.

So, here you can see, we are calculating these by taking the difference between the nutrient uptake in the above ground parts of the plant between the fertilized as well as the unfertilized crop. That means from the control plot, which related to the quantity of the applied nutrient. Another important term is physiological efficiency. So, this physiological efficiency or P can be, I mean, it is defined as the yield increase in relation to the increase in crop uptake of the nutrient in above ground parts of the plant.

So, again, it is basically yield increase in relation to the increase in crop uptake of the nutrient in above ground parts of the plant. So, it considers the yield increase as compared to the increase in, crop uptake, by the above ground plants. So, like this agronomic efficiency and this recovery efficiency, it needs a plot without application of the nutrient of interested to be implemented on the side, or in other words, for calculating the physiological efficiency, we also the control plot.

It also requires measurement of nutrient concentration in the crop and is mainly measured and used in research. So, you can see that for calculating several of this term, we create a well-designed experiment in a farm so that we can calculate this nutrient used efficiencies.

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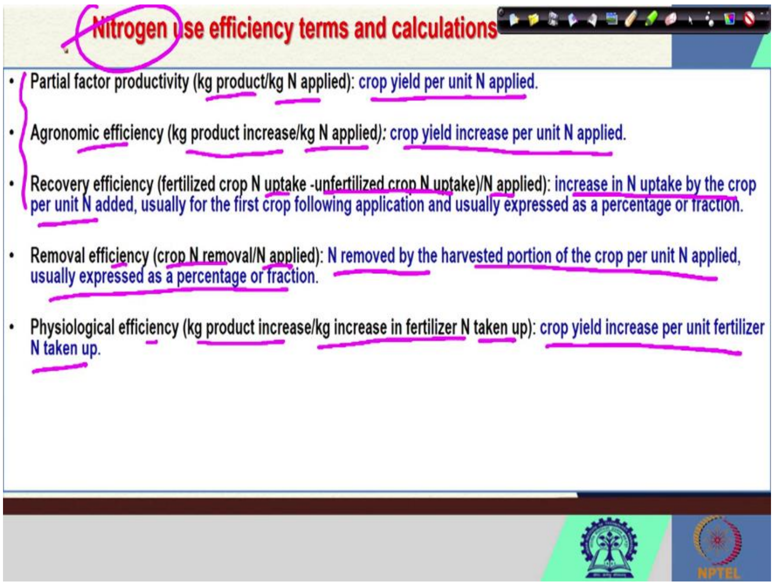

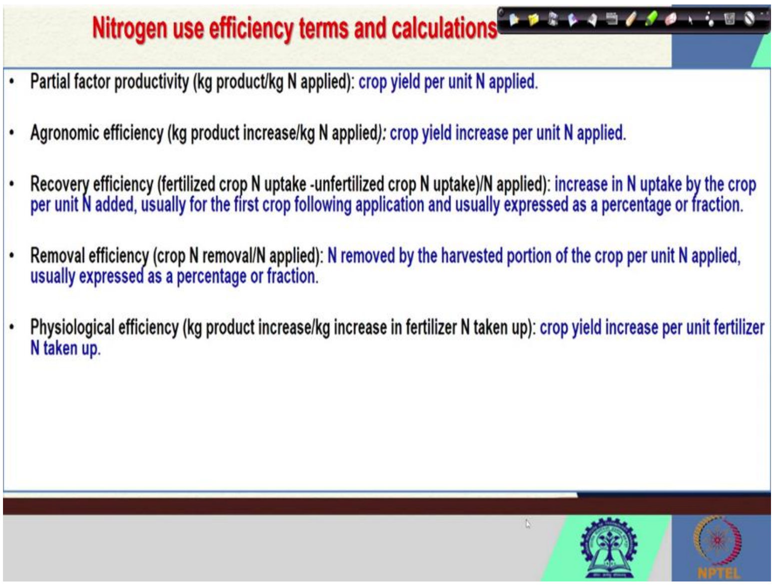

Now how to calculate these individual terms. So, here it has been clearly given. So, partial factor productivity, generally the unit is kg of product by kg of nitrogen applied. So, we can see crop yield per unit of nitrogen applied. Agronomic efficiency, we know kg product increase by kg of nitrogen and applied. So, crop yield increase per unit of nitrogen applied.

The recovery efficiency that is fertilized crop nitrogen uptake minus unfertilized crop nitrogen uptake by nitrogen applied, or when we call it, I mean, for example, if you consider this recovery efficiency for a particular nutrient suppose, this is nitrogen. So, if you consider this recovery efficiency of nitrogen, so we will see that fertilized crop nitrogen uptake minus unfertilized crop nitrogen uptake by nitrogen applied.

So, here, all these calculations are being done based on nitrogen and nitrogen applied. So, increase in nitrogen uptake by the crop by unit of nitrogen added and it is usually for the first crop following application, and usually expresses a percentage or fraction. So, this is recovery efficiency. Next is removal efficiency of nitrogen. So, crop nitrogen and removal by nitrogen applied.

So, nitrogen removed by the harvested portion of the crop per unit nitrogen applied, usually expresses a percentage or fraction, and finally physiological efficiency that is kg product increased by kg increase in fertilizer nitrogen taken up. So, we can see there is crop yield increase per unit fertilizer nitrogen taken up. So, this is how we can calculate these nutrient efficiency terms for nitrogen and for other nutrients also.

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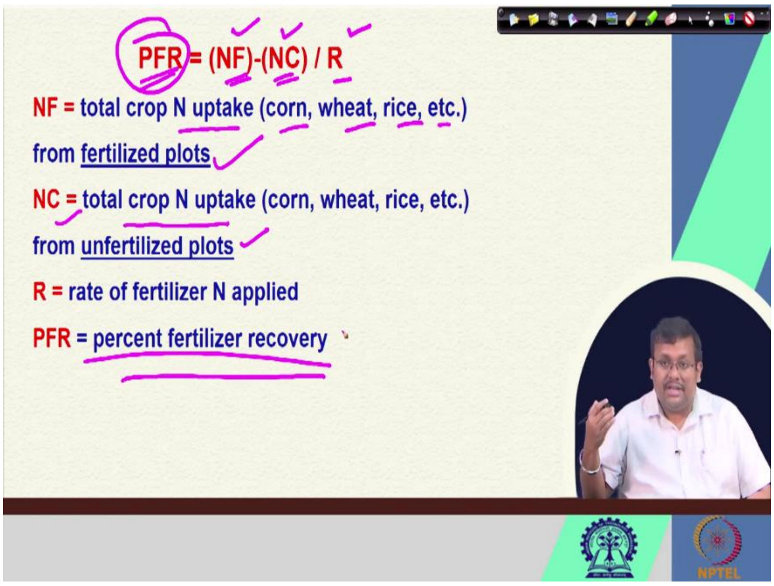

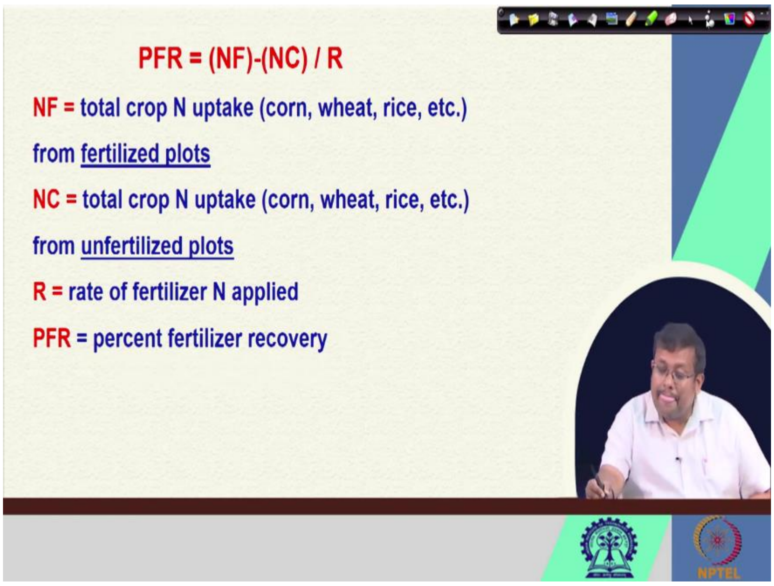

Now let us move ahead and see another important term that is percent fertilizer recovery. So, Percent fertilizer recovery is generally, denoted by this short PFR and this is NF minus NC by R. Now what is NF? NF is total if let us consider that we are calculating these PFR for nitrogen. So, these NF terms that no total crop nitrogen uptake for different crops like corn, wheat, rice, et cetera, from fertilized plots and NC stands for total crop nitrogen uptake from unfertilized plots or control plots.

So, this is nitrogen uptake from the fertilized plot minus nitrogen uptake by the unfertilized plot by the rate of fertilizer nitrogen applied. So, this will give you PFR or percent fertilizer, recovery of nitrogen. So, this is how we can calculate these individual terms if by having by inputting these uptake as well as yield and also the rate of nitrogen and inputs.

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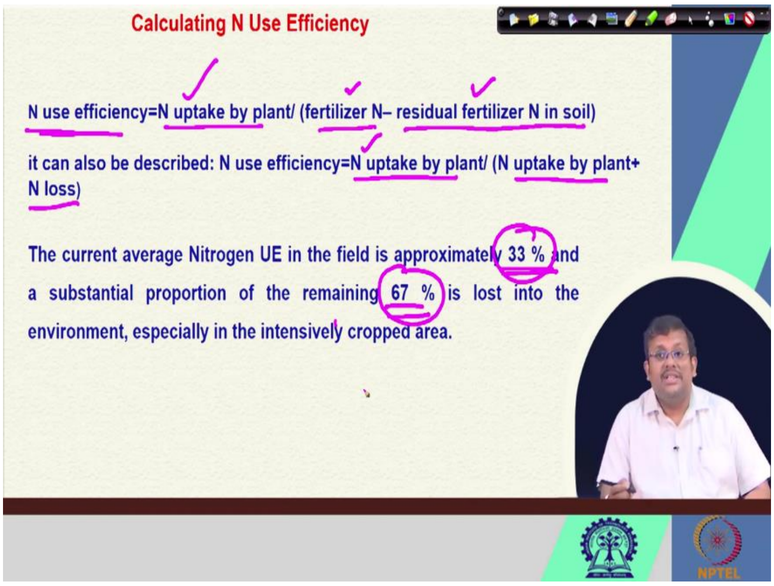

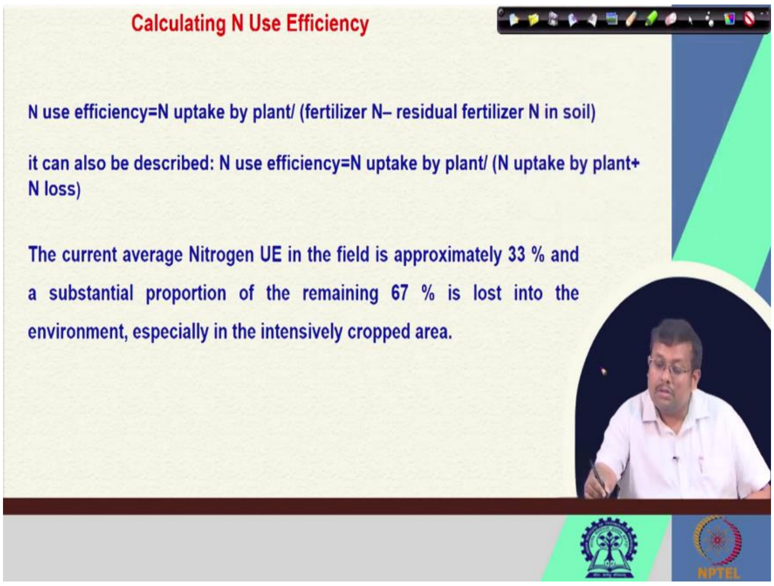

So, if we can, if nitrogen and use efficiency, as we know from our previous discussion, that it is basically nitrogen uptake by the plants by fertilizer nitrogen and minus receivable fertilizer nitrogen in soil. So, to be more precise than nitrogen use efficiency can be expressed as nitrogen uptake by the plant by fertilizer nitrogen minus residual fertilizer nitrogen in the soil. So, if we can input these valves, we will get the nitrogen use efficiency.

So, here you can see here, we both calculating the inputs of nitrogen as fertilizer, and also the residual fertilizer nitrogen which is present in the soil. So, it can be also described as nitrogen uptake by the plant by nitrogen uptake by plant plus nitrogen loss. So, nitrogen use efficiency can be expressed either by this way or by this way. So, in the first, method, we are considering the nitrogen uptake by the plant by fertilizer nitrogen minus residual fertilizer nitrogen in the soil.

And in the second method, we are considering nitrogen and uptake by the nitrogen uptake by plant and nitrogen and loss. So, the current average nitrogen use efficiency in the field is approximately 33 percent and it is remembered that a substantial proportion of the remaining 67 percentage is lost into the environment, especially in the intensively corrupt area.

So, that is why nitrogen and management is a very important aspect of fertilizer management in the soil and because 67, that means two third of the applied nitrogen in the soil get lost from the soil due to different types of processes and only 33 percent of the applied nitrogen is available to the plant.

So, we can clearly see that it is a major concern and that is why scientists are doing research worldwide to increase this nitrogen use efficiency in the plant to, I mean, in the soil, for the plant by using different types of measures. So, we are going to discuss those in our upcoming slides.

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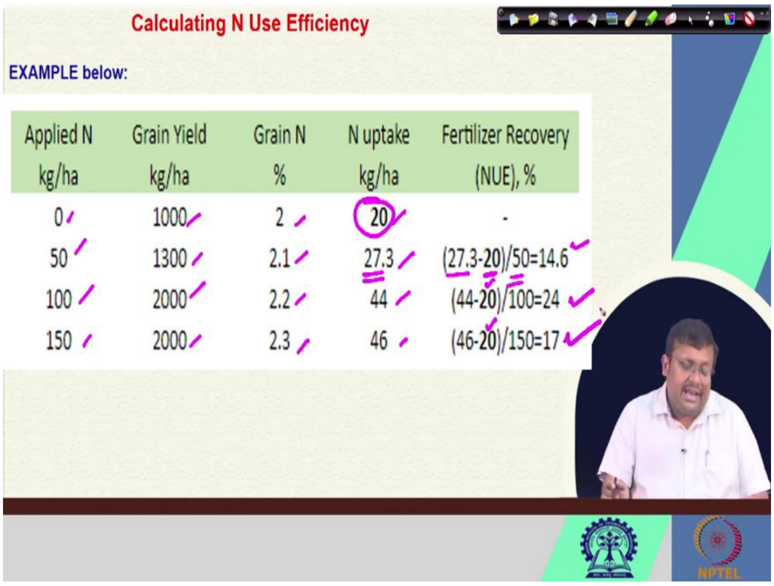

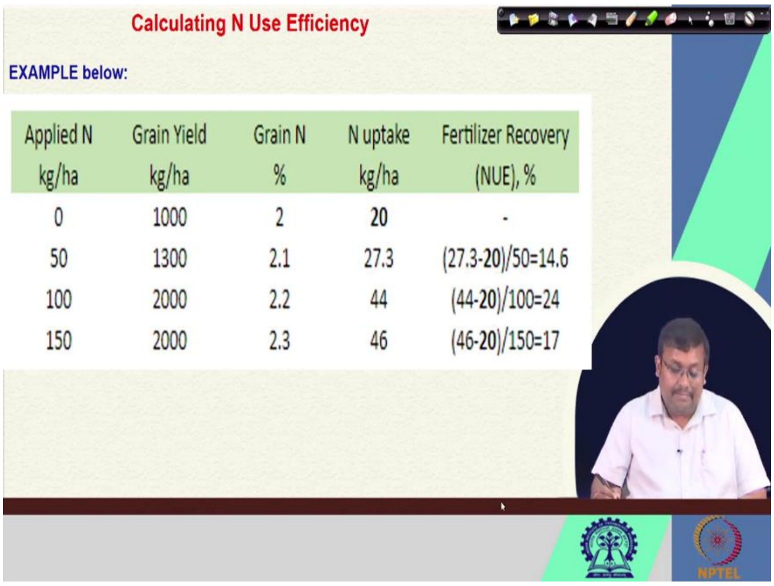

Applied N kg/ha	Grain Yield kg/ha	Grain N %	N uptake kg/ha	Fertilizer Recovery (NUE), %
0	1000	2	20	-
50	1300	2.1	27.3	(27.3-20)/50=14.6
100	2000	2.2	44	(44-20)/100=24
150	2000	2.3	46	(46-20)/150=17

Now, if you can see one example below, you can see that, here we are having applied nitrogen 0 kg per hector, 50 kg per hector, 100 kg per hector, 150 kg per hector, and we are getting 1000 kg yield per hector, 1300 kg, 2000 kg, 2000 kg. Subsequently, we know that 2 percent, 2.1 percent, 2.2 percent, 2.3 percent are the grain nitrogen and nitrogen uptake in kg per hector 20, 27.3, 44, and 46.

Now, if we want to calculate the fertilizer recovery or nitrogen use efficiency percentage, so you can see here that is, here in this case here, the nitrogen uptake is 27.3 minus 20, 20 is here nitrogen uptake from the unfertilized plot. So, 20 divided by 50 that is applied nitrogen and so, 14.6. So, you can see for all these different levels, we are putting these values of 20 to account for this nitrogen and uptake from the unfertilized plot or control plot and then we are basically dividing it by the applied nitrogen and to get the fertilizer recovery or nitrogen use efficiency. So, this is how we can calculate this nitrogen and use efficiency.

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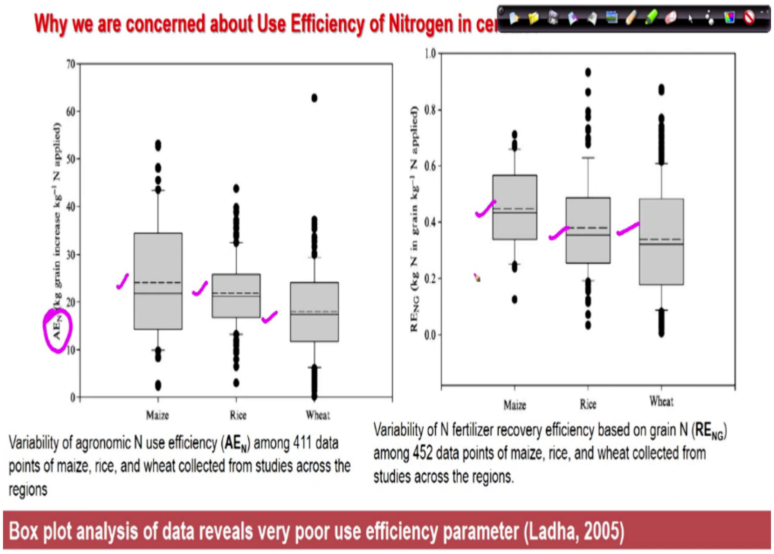

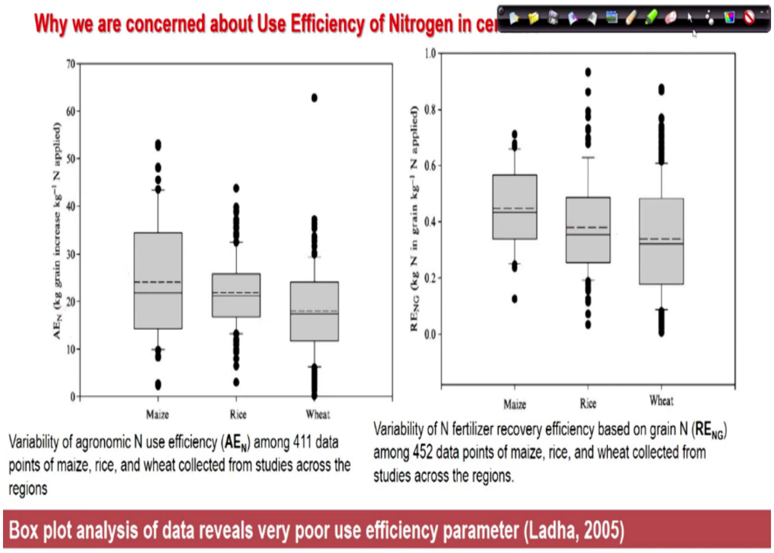

Now why we are concerned about use efficiency of nitrogen and in cereal. So, if you can see this shows, the box plots of agronomic efficiency and recovery efficiency of nitrogen for three different crops, one is maize other one is rice and there is wheat. So, if you can see the average agronomic efficiency, as well as the average recovery efficiency of maize is highest followed by rice and wheat.

So, this is very important that we should be concerned about nitrogen use efficiency in the cereals, because you can see here clearly that the average values are remaining within around 20 to 30 for these agronomic efficiency remains for these three crops, the mean agronomic efficiency of these three crops remain in and around 20 to 30 and also here, the recovery efficiency is also, within only 30 to 40 percentage.

So, this shows that why we should be very much concerned about efficiency of nitrogen use efficiency specifically in cereals.

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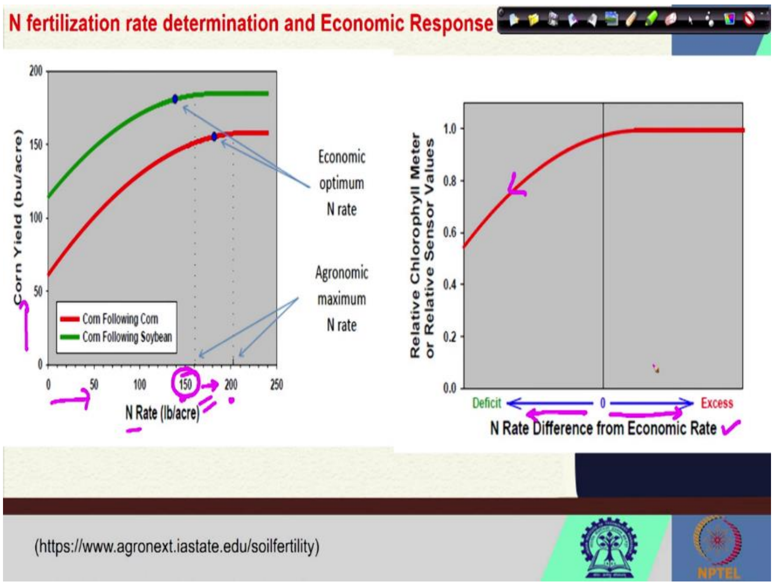

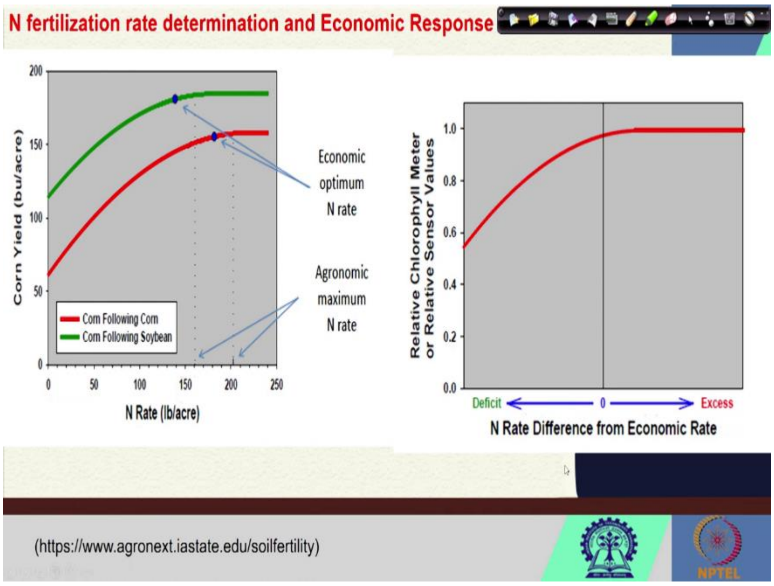

Also, if we want to see the optimum nitrogen and fertilization for better economic response, these graphs will give us some good idea. So, here you can see, as we are increasing the nitrogen and application in the X axis, and we are getting the corn yield, of one is the red one is the corn following corn, and the green one is corn following soybean. So, you can see that as we are increasing the fertilizer application from 150 pound per acre to 250, 200 pound per acre.

So, we are not getting the increase in E the corn yield or subsequent economic optimum economic return is not increasing in a steeper slope. So, that means we should be very, very careful to find the threshold where we should stop for the nitrogen and application, so we can call it an agronomic maximum nitrogen and rate and here you can see economic optimum nitrogen and rate is getting, we are getting economic max optimum nitrogen rate in and around when our fertilizer replication is around 150 pound per acre.

So, that means we should not increase our fertilizer replication after a certain threshold, because our return will not be maximized in a similar proportion. So, we should stop application there, here in the second graph also, it is clear. So, here you can see the nitrogen rate difference from the economic rate. So, if we are giving higher nitrogen than excess of nitrogen then from the optimum economic rate, then we can see there is a plateau of relative chlorophyll meter or relative sensor value.

So, we will not get any higher yield, but if we did, if we have a deficit amount of nutrient from this economic optimum economic rate, we can get the reduction in yield. So, that shows again, to find a sweet spot or find a threshold of nitrogen used, where we should get the optimum economic return. Otherwise, these will not be sustainable for long duration. So, nitrogen fertilizer application should consider this economic response very carefully, so that we can find the optimum threshold for nitrogen application in the field.

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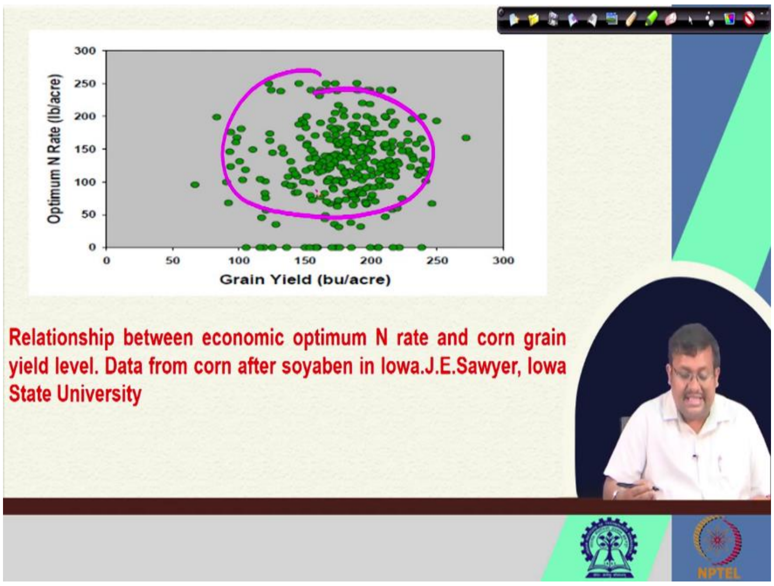

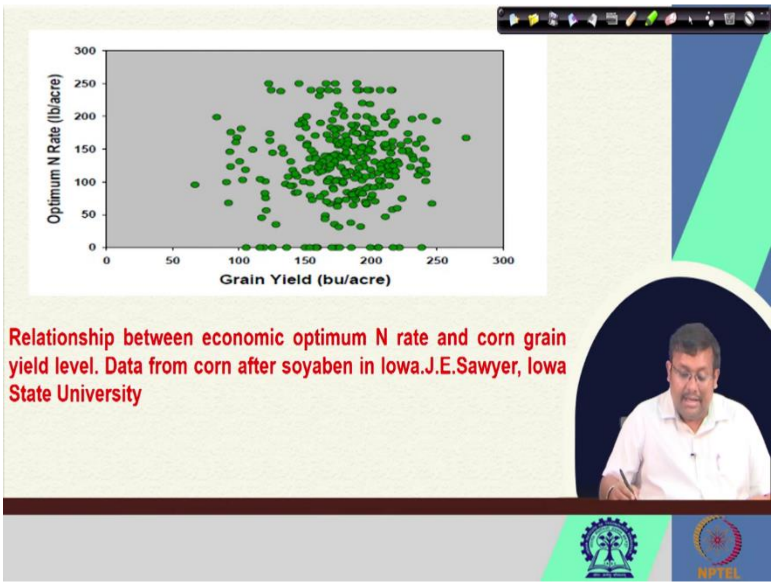

Now, here also you can see this is a scattered plot between grain yield by optimum nitrogen rate in pound per acre. So, we can see this is basically economic optimum nitrogen rate and corn grain yield level. So, one thing is for sure that when the grain yield is from 100 to around 250, bushels par acre, the maximum nitrogen or optimum nitrogen, application is clustered around these 100 within 150 to 200.

So, that shows that we should find a threshold value of which satisfy the maximum grain yield. So, this basically further justifies the importance of considering the economic return when we apply the fertilizer nitrogen in that soil.

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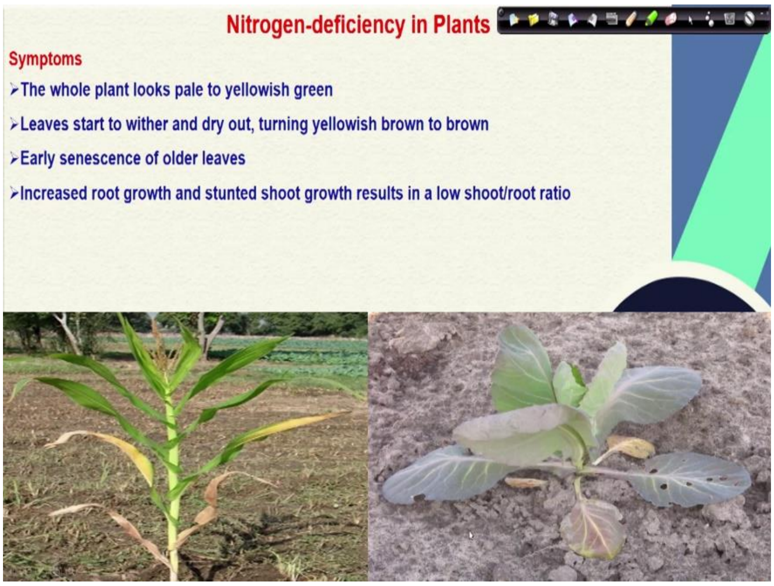

Now, what are the nitrogen deficiency symptoms in the plant? Now, the whole plant looks pale to yellowish green and leaves start to wither and dry out. As you can see, the whole plan looks pale to yellowish green and the leaves starts to wither and dry out turning yellowish brown to brown. Early senescence of the older leaves. So, you can see these are the older leaves.

So, early senescence you can see, and also increased root growth and stunted shoot growth results in a low shoot to root ratio. So, these are some of the symptoms of nitrogen and deficiency in the plants. And these are some of the photographs you can see clearly that plant is turning, yellow as a result of nitrogen and deficiency.

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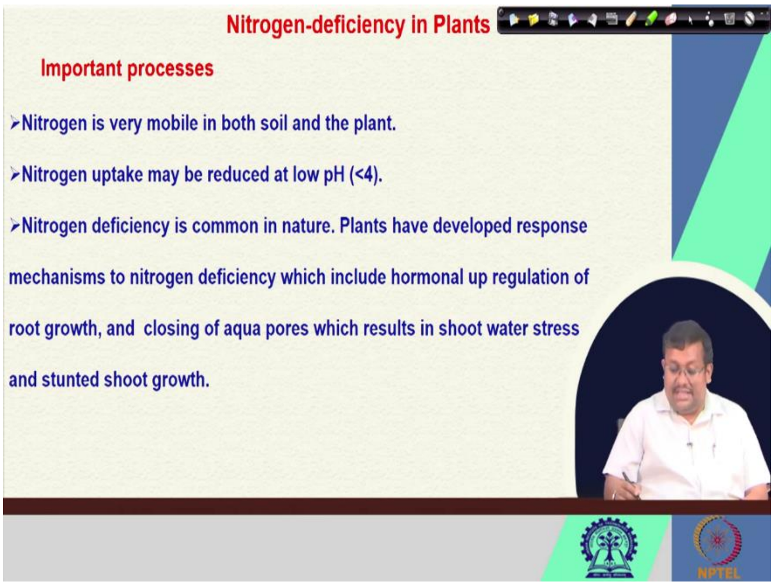

So, what are the important process when there is a nitrogen deficiency. Nitrogen, that is very mobile in both soil and plant and nitrogen uptake may be reduced, when the pH of the soil falls below, 0. So, nitrogen in deficiency is very common but plants have developed, response mechanism to this nitrogen and deficiency. And what are those response mechanism?

The response mechanism is hormonal up regulation of root growth and closing of aqua pores which results in shoot water stress and stunted shoot growth. So, these are some of the mechanisms which plant have developed when there is a nitrogen deficiency in the soil.

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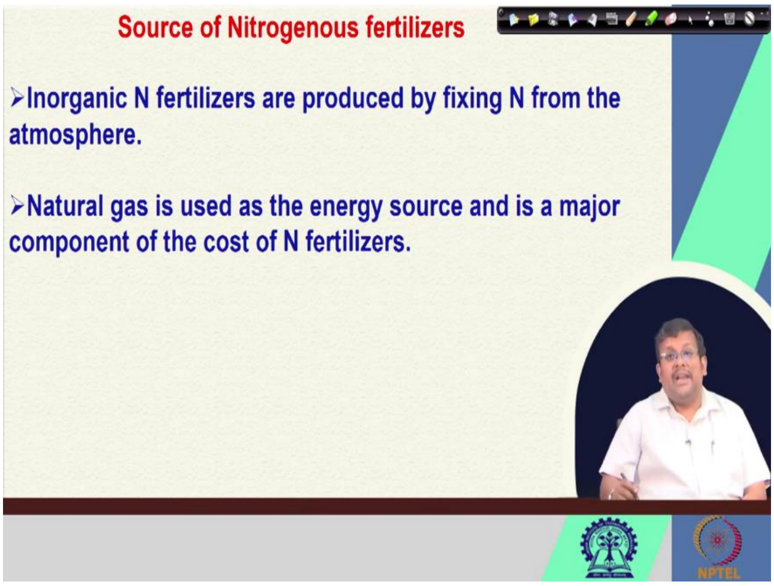

So, there are different sources of nitrogenous fertilizer, inorganic nitrogen is fertilizer are produced by fixing nitrogen from the atmosphere and natural gas is used as that energy source and is a major component of the cost of nitrogen fertilizers.

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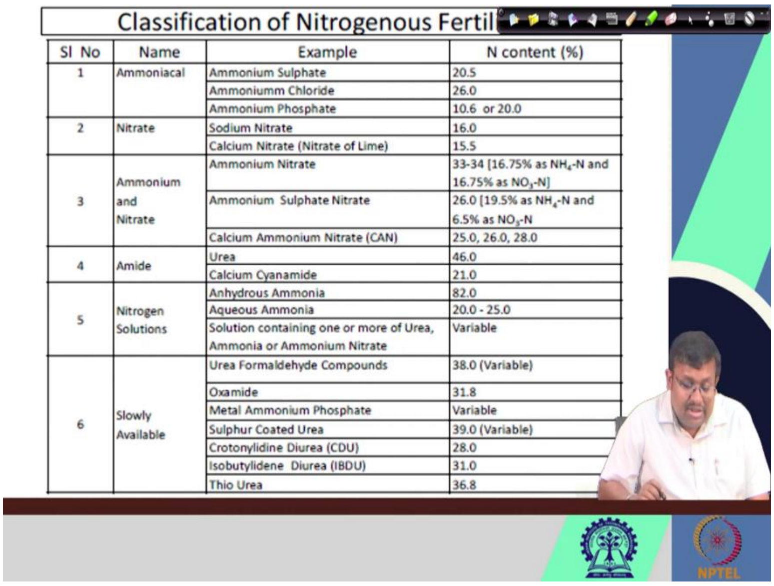

Classification of Nitrogenous Fertil

Sl No	Name	Example	N content (%)
1	Ammoniacal	Ammonium Sulphate	20.5
		Ammoniumm Chloride	26.0
		Ammonium Phosphate	10.6 or 20.0
2	Nitrate	Sodium Nitrate	16.0
		Calcium Nitrate (Nitrate of Lime)	15.5
3	Ammonium and Nitrate	Ammonium Nitrate	33-34 [16.75% as NH_4-N and 16.75% as NO_3-N]
		Ammonium Sulphate Nitrate	26.0 [19.5% as NH_4-N and 6.5% as NO_3-N
		Calcium Ammonium Nitrate (CAN)	25.0, 26.0, 28.0
4	Amide	Urea	46.0
		Calcium Cyanamide	21.0
5	Nitrogen Solutions	Anhydrous Ammonia	82.0
		Aqueous Ammonia	20.0 - 25.0
		Solution containing one or more of Urea, Ammonia or Ammonium Nitrate	Variable
6	Slowly Available	Urea Formaldehyde Compounds	38.0 (Variable)
		Oxamide	31.8
		Metal Ammonium Phosphate	Variable
		Sulphur Coated Urea	39.0 (Variable)
		Crotonylidine Diurea (CDU)	28.0
		Isobutylidene Diurea (IBDU)	31.0
		Thio Urea	36.8

So, here, there are several classifications, these are classification of nitrogenous fertilizers. You can see here, ammonium sulphate, which contains 20.5 percent nitrogen ammonium chloride, 26 percent nitrogen, ammonium phosphate. So, these are the ammoniacal fertilizer. What are the nitrate fertilizer?

Sodium nitrate which contains 16 percent nitrogen, calcium nitrate which contains 15.5 percent nitrate and both ammonium and nitrate form are containing in this fertilizer like ammonium nitrate which contains 33 to 34 percent of nitrous and ammonium sulphate nitrate, calcium ammonium nitrate or CAN, these are fertilizers, nitrogen as fertilizers which contain both ammonium and nitrate form.

Urea the most widely used nitrogenous fertilizer is it is an amide fertilizer and it contain 46 percent nitrogen. Calcium cyanamide contains 21 percent nitrogen. Nitrogen solutions are being also used like anhydrous ammonia contain 82 percent nitrogen and aqueous ammonia contain 20 to 25 percent nitrogen and so on. Slowly available fertilizers, nitrogen fertilizers are there like urea formaldehyde compounds, urea form and then oxamide, metal ammonium phosphate, sulphur coated urea, CDU, then IBDU, thio urea.

These are several variations of slowly available nitrogenous fertilizers and we are going to discuss this in our upcoming slides.

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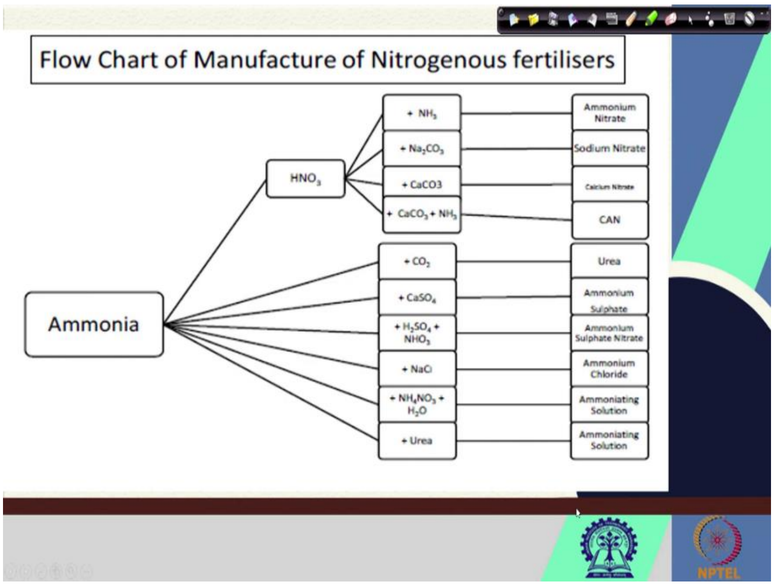

But so, these are the basic classification of nitrogenous fertilizers. Now this flow chart shows that manufacture of nitrogenous fertilizers. The major component is ammonia when ammonia is reacted with the, we have discussed how we can produce the ammonia by Haber and Bosch process. So, when we react this ammonia with nitrate, nitric acid, and then ammonia, then it produces the ammonium nitrate.

Then sodium carbonate, when it reacts with sodium carbonate, we get sodium nitrate, calcium carbonate reaction produces calcium nitrate, calcium carbonate ammonium produce calcium ammonium nitrate. Ammonia plus carbon dioxide produce urea. Ammonia calcium sulphate produce ammonium sulphate, and the then so on so forth. So, these flow chart shows the manufacturer of nitrogenous fertilizers.

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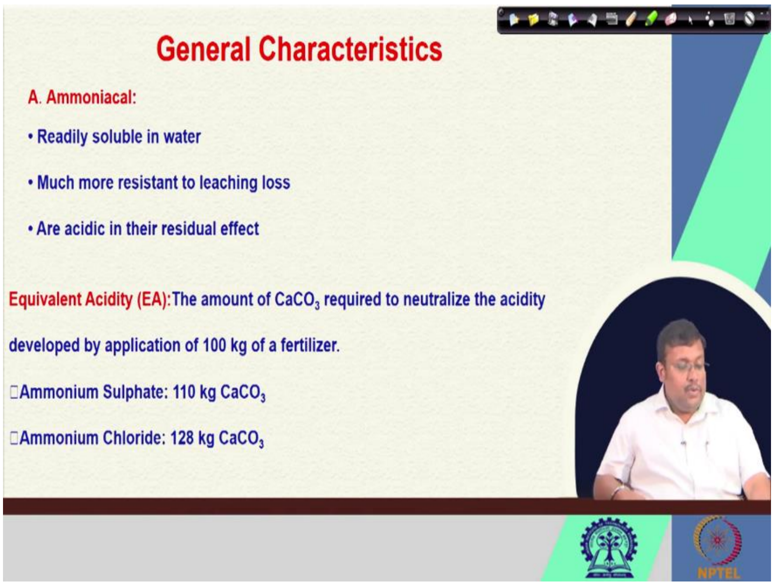

Now, if you see the general characteristics of ammoniacal fertilizers, they are readily soluble in water, and they are much more resistant to the leaching loss, and they are acidic in their residual effect. Now, there is a term called equivalent acid or EA. So, this is basically the amount of calcium carbonate, which is required to neutralize the acidity developed by application of a 100 kg fertilizers.

So, there are several fertilizers like ammonium sulphide, ammonium chloride. These are acid forming fertilizers. So, when we apply these fertilizers in the soil, they create the acidic condition. So, to equivalent acidity is basically the amount of calcium carbonate or lime required to neutralize the acidity developed by application of a 100 kg of this fertilizer. So, the equivalent acidity of ammonium sulphate is 110 kg and equivalent acidity of ammonium chide is 120 kg.

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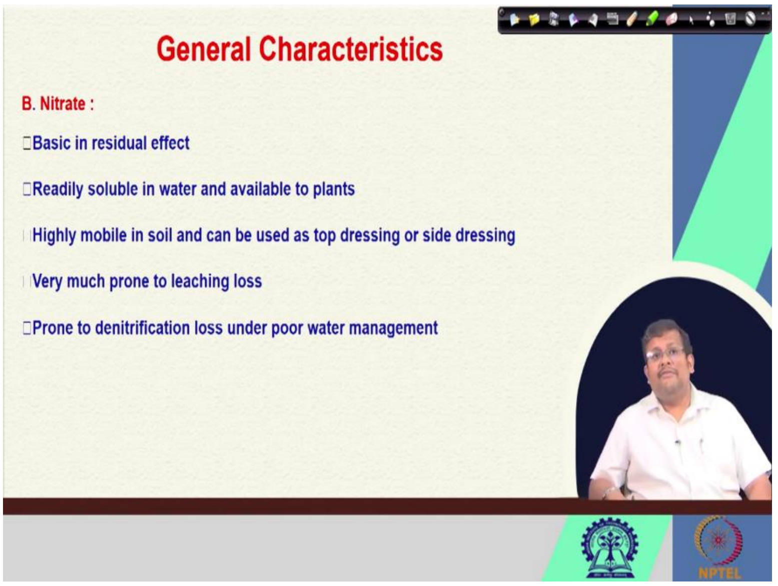

Now, nitrate fertilizers. So, they are generally basic in residual effect, and they are also readily soluble in water and available to the plants. They are highly mobile in soil can be used as top dressing or side dressing, and they are very much prone to leaching process I have told you, nitric fertilizers are very much prone to leaching loss.

And they are also prone to denitrification loss under poor water management. We know what is denitrification loss, it is the conversion of nitrate to gases nitrogen anaerobic condition. So, these are some of the phases of nitrate fertilizer.

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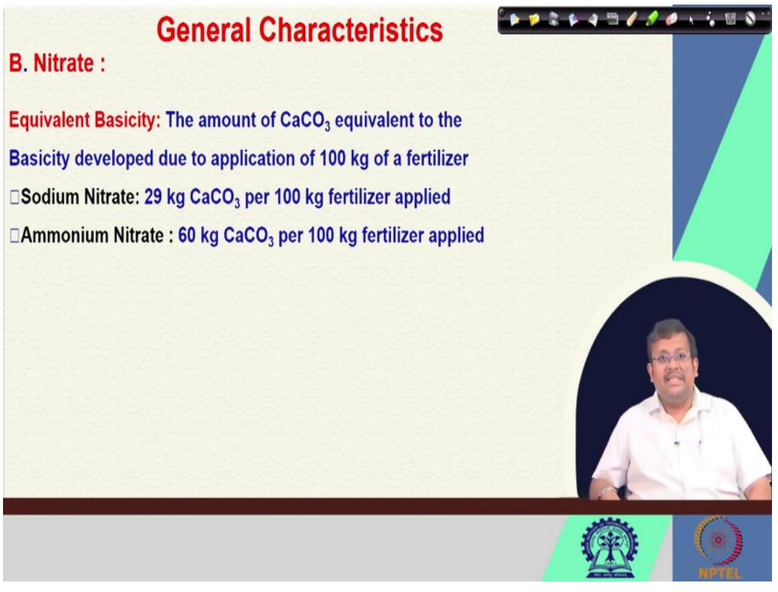

Now, there is another term called equivalent basicity. Now as these, since the nitrate fertilizer are basic in nature, there is a term called equivalent basicity. So, the amount of calcium carbonate equivalent to the basicity developed due to the application of 100 kg of the fertilizers. So, sodium nitrate is basically having the 29 kg of calcium carbonate per 100 kg of fertilizer applied and 60 kg of calcium carbonate per 100 kg of fertilizer applied in case of ammonium nitrate. So, these are equivalent basicity of these fertilizers.

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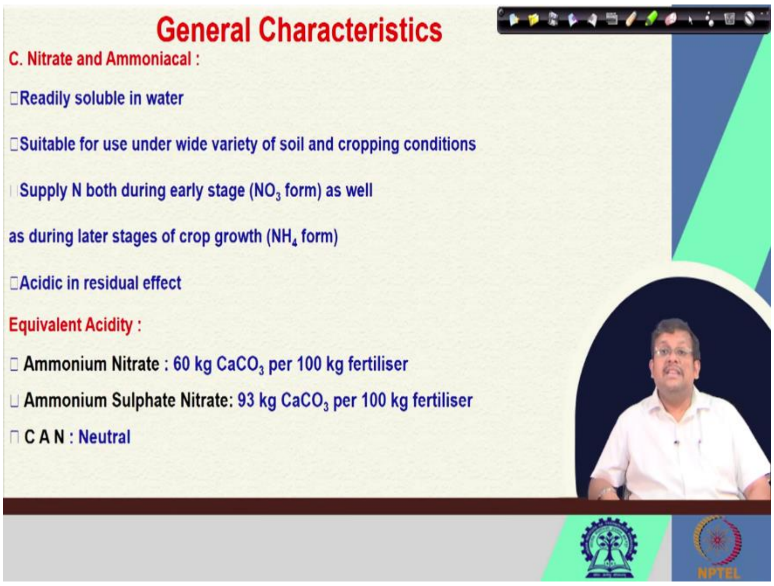

Now, some new fertilizer like CAN, calcium ammonium nitrate. They are having both the nitrate and ammonium, ammoniacal nitrogen. So, they are readily soluble in water. They are suitable for use under wide variety of soil and cropping condition and they supply nitrogen both during early stage in the nitrate form as well as during the latest stage in the crop growth in the ammonia form and they are acidic in the residual effect.

So, equivalent acidity, for example, in case of ammonium nitrate it is 60. In case of ammoniacal ammonium sulphate nitrate it is 93 and in case of CAN, that is calcium ammonium nitrate which is a neutral fertilizer.

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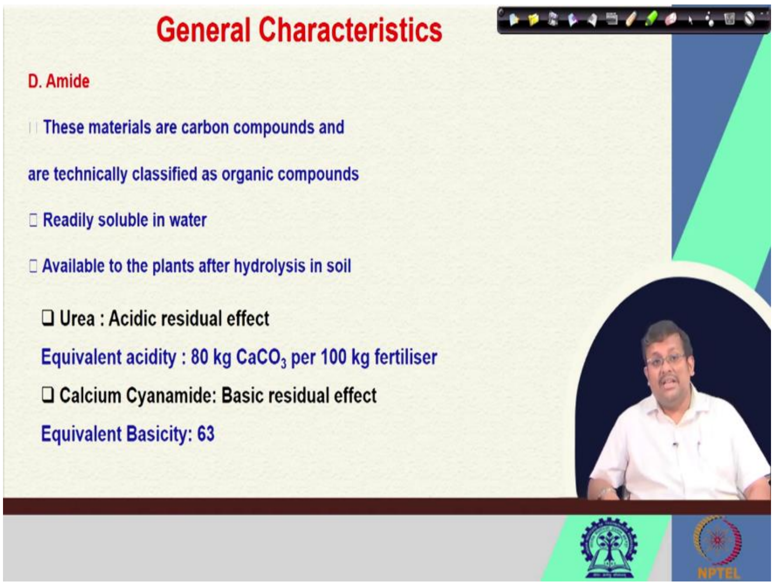

And fourth one is the amide fertilizer. So, these materials are carbon compound and are technically classified as organic compound like urea and they are available to the plants after hydrolysis. So, urea is a fertilizer, which is widely used by the farmers, and these are acidic in residual effect. So, equivalent acidity of urea is 80 kg calcium carbonate per 100 kg of urea and calcium cyanamide, which is having basic residual effect equivalent basicity is 63.

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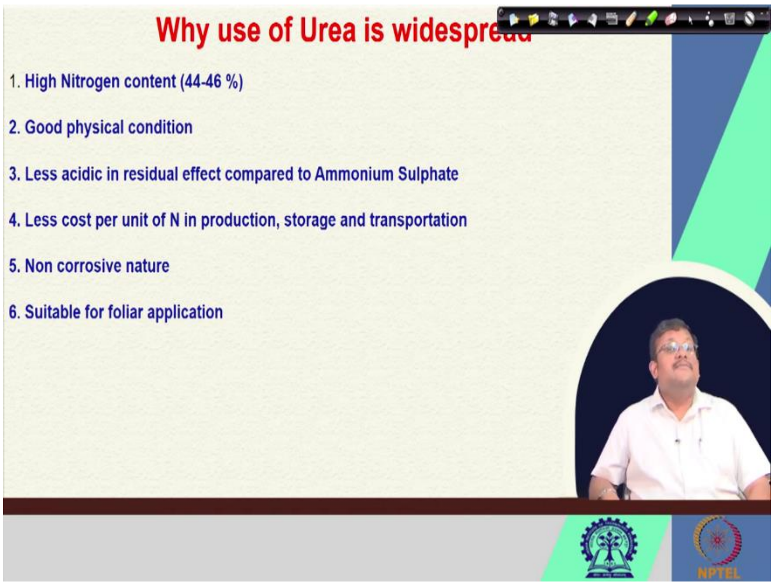

So, why we prefer urea and why urea is widespread because it has high nitrogen content, 44, 46 percent. It has good physical condition. It is less acidic in residual effect compared to ammonium sulphate. It is less cost per unit of nitrogen in production storage and transportation, and, noncorrosive in nature. And finally, it is also suitable for foliar applications. So, these six advantages helped urea to become most widely used nitrogenous fertilizers.

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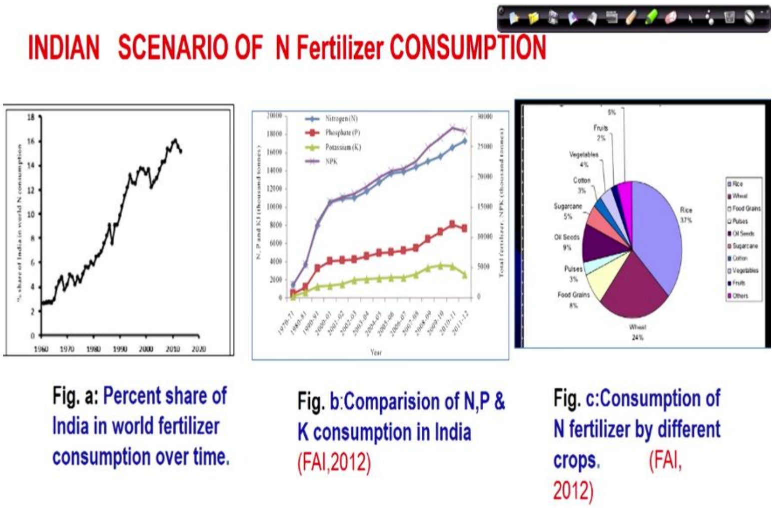

So, if we see the Indian scenario of nitrogen fertilizer consumption in all these three graphs, we can clearly see that percentage share of India in one fertilizer consumption over time is increasing since 1960 and if you see the companies of nitrogen, phosphorus, and potassium consumption in India, of course, the nitrogen consumption has been increased more than phosphorus and potassium and NPK fertilizers are also having high consumption since 1970s, the last 50 years.

And if you see the consumption of N fertilizer by different crops, of course, rice and wheat accounts for the major share of consumption of nitrogenous fertilizer.

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So, guys, we have completed this lecture and I hope that you have got knowledge of some important terms specifically the nutrient use efficiency terms and, these are the references. And, we will start from here in the next lecture and we will discuss some of the important aspects of nutrient management and fertilizer management, nitrogenous fertilizer management. Thank you very much.