Soil Fertility and Fertilizers
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Lecture 1
Importance of Soil Nutrient Management and Basic Soil-Plant Relationship

Welcome friends to this NPTEL online certification course of Soil Fertility and Fertilizers. And we are at week 1 and in this week we are going to discuss the importance of soil nutrient management and basic soil plant relationship.

So, today we are going to discuss our first lecture and we are going to see the basic overview of soil nutrient management as well as what are the importance of soil nutrient, we are going to learn some of the important terminologies and also we are going to discuss the some of the important nutrient related relationship with the with the plant growth.

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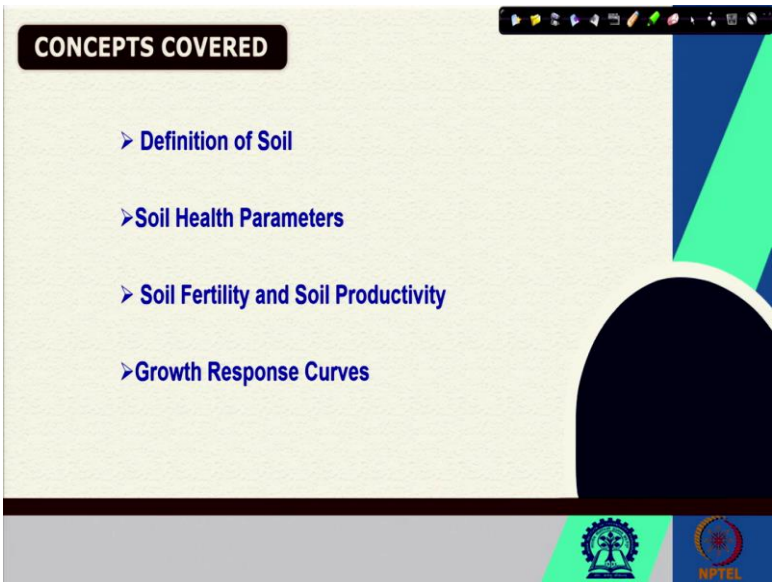

So, let us start and these are the concepts which we are going to discuss in this lecture. First of all we are going to see the definition of soil and then soil health parameters we are going to discuss and then we are going to discuss the soil fertility and soil productivity what is the, what are the differences between soil fertility and soil productivity and lastly, we are going to discuss the growth response curves.

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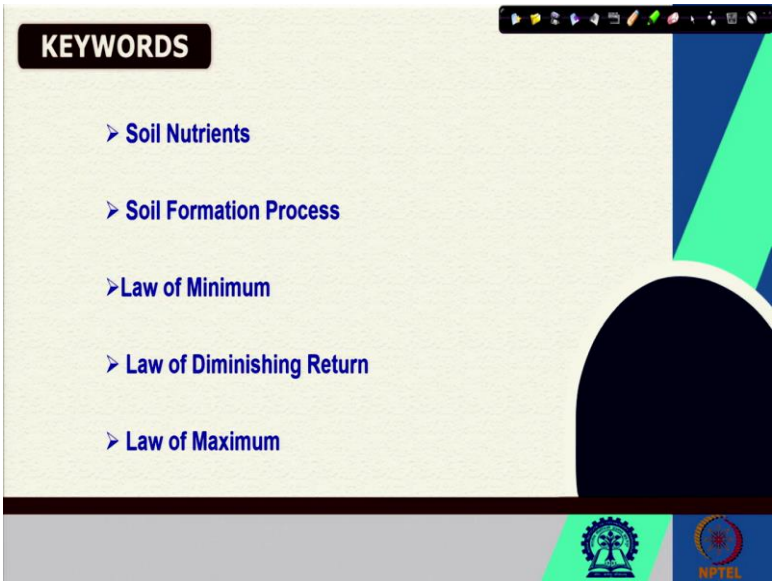

These are the some of the keywords soil nutrients, soil formation process, law of minimum, law of diminishing return, law of maximum, we are going to discuss all these in this in this first lecture.

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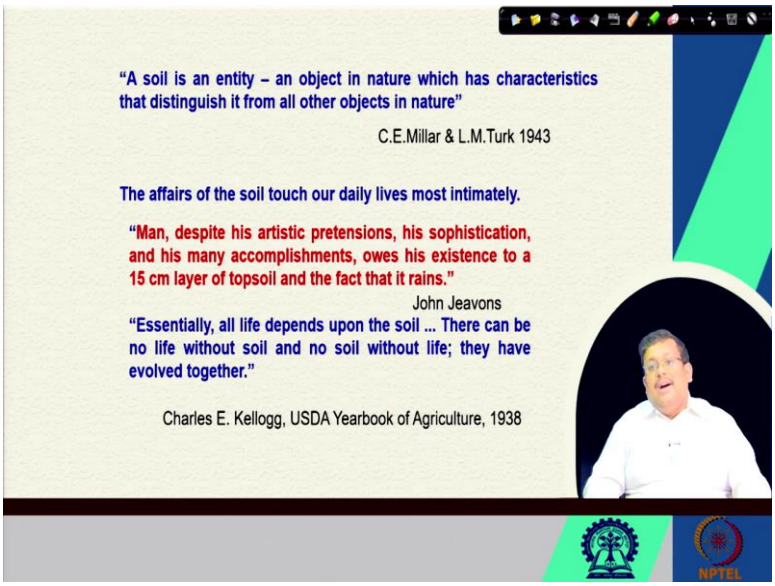

So, let us start with the definition of the soil. Now, we all know that soil is a heterogeneous mixture, if you have followed my, my soil science and technology NPTEL course I have defined, I have given the basic definition of the soil. Now, the basic definition of soil says it is a heterogeneous mixture comprised of both the solid metrics as well as water as well as air and in the solid metrics you can see both the mineral matter as well as the soil organic matter.

However, from the ancient time, different philosophers as well as scientists have defined the soil in their own manner. So, we can we can discuss couple of them. So, according to C.E. Millar and Turk in 1943, they have defined that a soil is an entity, an object in nature, which has characteristics that distinguish it from all other objects in nature.

So, they are emphasizing that soil itself a unique matter in the unique, unique entity in the in the whole ecosystem, that has their own separate characteristics, which can be clearly, you can distinguish from the other matters. Apart from that John Jeaavons has defined the soil as "Man, despite his artistic pretensions, his sophistication and his many accomplishments, owes his existence to a 15 centimeter layer of topsoil and the fact that it rains."

Now, that implies the importance of why soil management is becoming a crucial term in contemporary environmental management. Charles Kellogg from USDA, Yearbook of Agriculture, 1938. He defined, "Essentially all life depends upon the soil, there can be no life without soil and no soil without life, they have evolved together." So, he is pointing out that life cannot be, a life cannot sustain without the presence of the soil.

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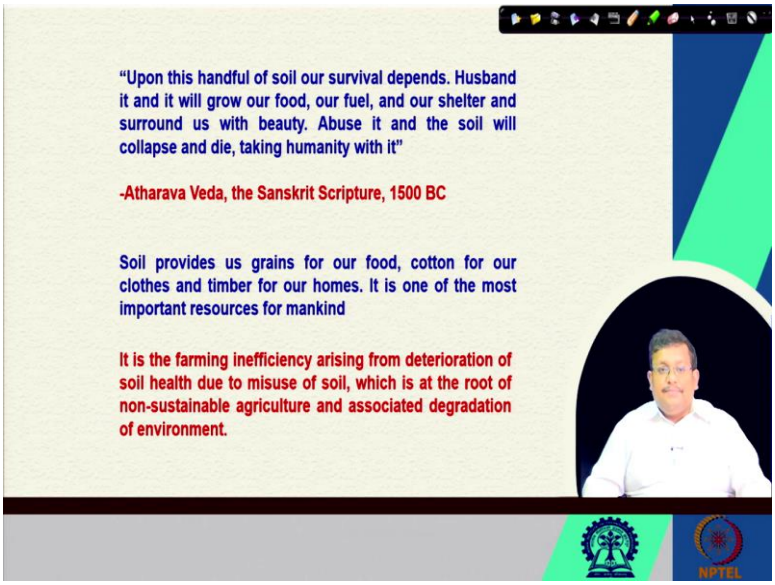

Now, in India, we have seen in Atharva Veda, the Sanskrit Scripture of 1500 BC, they have also mentioned the importance of the soil. So, there is a mention that "Upon this handful of soil, our survival depends. Husband it will grow our food, our fuel, and our shelter and surround us with beauty. Abuse it and the soil will collapse and die taking humanity with it".

So, that means, that in that ancient time also people have realized the importance of the soil. Now, soil provides us grains for our food, cotton for our clothes and timber for our homes, it is one of the most important resources for mankind.

Now, it is farming efficiency arising from deterioration of soil health, due to misuse of soil, which is at the root of non sustainable agriculture and associated degradation of environment. So, how we manage our soil is important and our farming efficiency, in efficiency you can tell plays an important role for managing for sustainably managing the soil resources of the earth.

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Now, we already know that soils are not merely an accumulation of debris resulting from decay of rock and organic materials, these are developed as rocks and are, as rocks are weathered and covered with organic materials.

Now, we all know that how soil develops? Soil develops from rocks and due to, I mean, it takes hundreds to millions years of a continuous different weathering process as well as different types of pedogenic processes for developing one inch of topsoil.

Now, it says clearly that it takes about 500 years for one inch of topsoil to form. So, soil forms in layers we know and from the rocks due to different types of physical chemical and biological weathering apart from different pedogenesis, they convert into soil.

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Now, the most important term of this lecture is soil health, what is soil health? How we define soil health and how we measure soil health? Now, soil health is basically the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health.

So, it is a comprehensive term, which shows the ability of the soil to maintain or to sustain the biological productivity to maintain the environmental quality and promote plant and animal health at the same time. Remember that a healthy soil would ensure proper retention and release of water and nutrients, it promote and sustain root growth, maintain soil biotech habitat, respond to management and resist degradation.

So, that is why a maintaining the soil health is of utmost importance for natural resource, the people for who are dealing with different types of natural resources.

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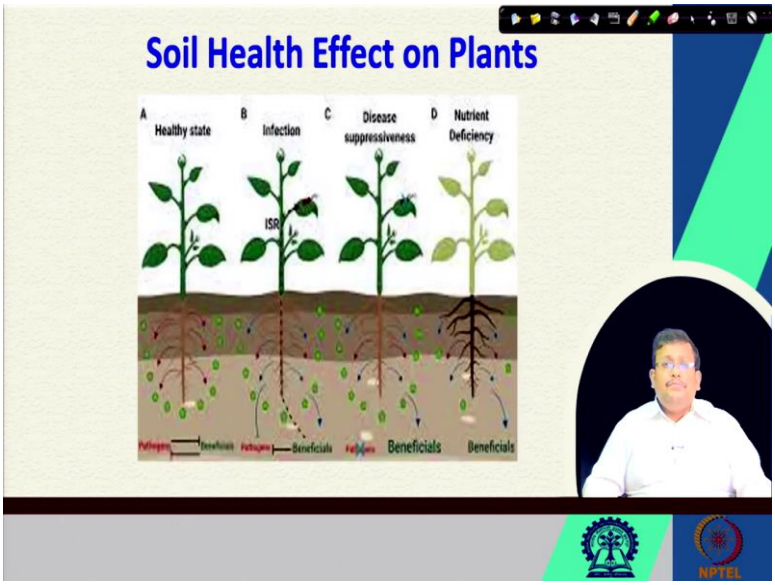

So, if you see the soil health effects on the plants, in this picture, you can see the healthy state this first plant is showing the healthy state and here we are, it is we are seeing that there is abundance of different nutrients. Of course in the soil, there are different types of pathogens as well as beneficial microorganisms.

However, when they are at equilibrium, we can see that plants are showing the healthy state. Of course, when the pathogen dominates and impacts the plant that can produce the infection in the plants. And also there is disease oppressiveness and finally, you can see the nutrient deficiency. Nutrient deficiency occurs when you can see there is a clear depletion of the nutrients around the roots or edge of sphere.

So, that shows the effect of soil health on plants, if the soil is healthy, then you can see the healthy state of the plant, if the soil is not healthy, then you can see there is different types of either nutrient deficiency or there could be manifestation of different types of diseases. Now, we can see here in an inhaled state, of course there will be an equilibrium between the beneficial microorganisms and of course there will be pathogens, but at the same time there should be adequate amount of nutrients are also.

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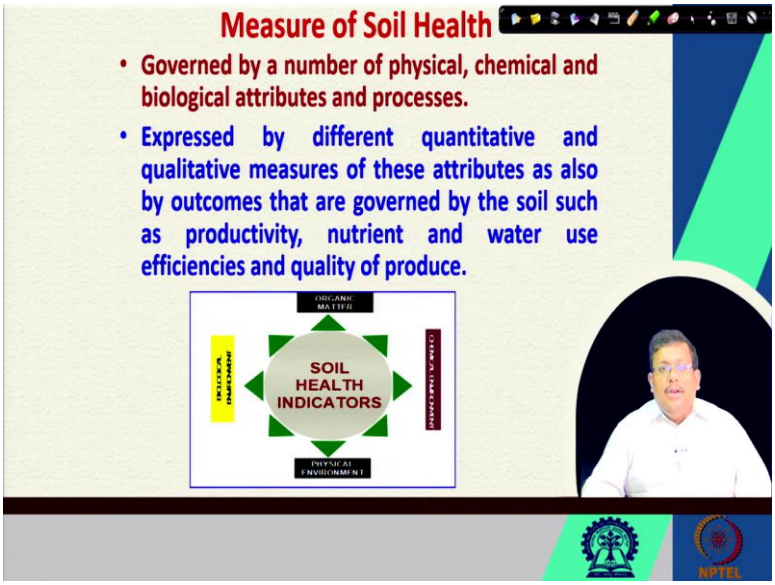

Now, we can see how to measure the soil health. Now, as I have mentioned that the soil health is governed by a number of physical, chemical and biological attributes and processes, and these measurement of soil health is expressed by different quantitative and qualitative measures of these attributes.

So, also by outcome, that are governed by soil such as productivity, nutrient and water use efficiencies and quality of the produce. So, if you can see that the what are the different players of soil health indicators, you can see that chemical environment is an important component then physical environment is another important component, then biological environment is another important component.

And of course, as I have pointed out many times, previously in my other courses, soil organic matter is one of the major indicator of soil health condition. So, you can see that the soil health indicators can be grouped into these four categories and all of these are important and they impact the soil ultimate soil health.

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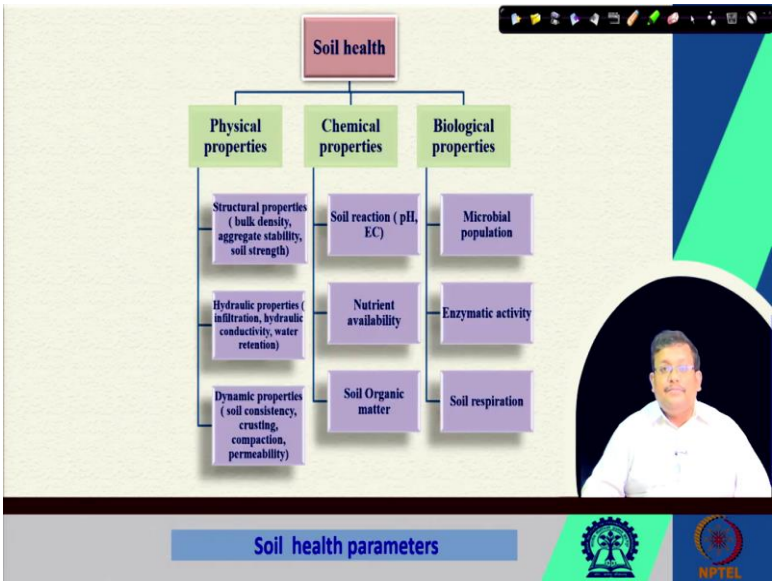

Now, if we classify the soil health into three categories like physical properties, chemical properties and biological properties, we can see that among the physical properties, we can see the structure properties are important, what are the structural properties? Some of the structural properties you can see bulk density, aggregate stability and soil strength, it gets hydraulic properties, infiltration, hydraulic conductivity, water detentions are important.

And some dynamic soil physical properties are also important like soil consistency, crusting, compaction and permeability, those who have not gone through these terms, I would request you to go through the my soil science and technology lectures which are available, which are also available freely in YouTube.

In the chemical properties, you can see that soil reaction and electrical conductivity are the two most important soil chemical properties which are regulating the soil health. Apart from that the nutrient availability and as I have mentioned soil organic matter play an important role for maintaining the soil health. Now, regarding the biological properties of course, microbial population, enzymatic activity and soil respiration these three are important indicators or I would say they are important factors for biological factors for controlling the soil health.

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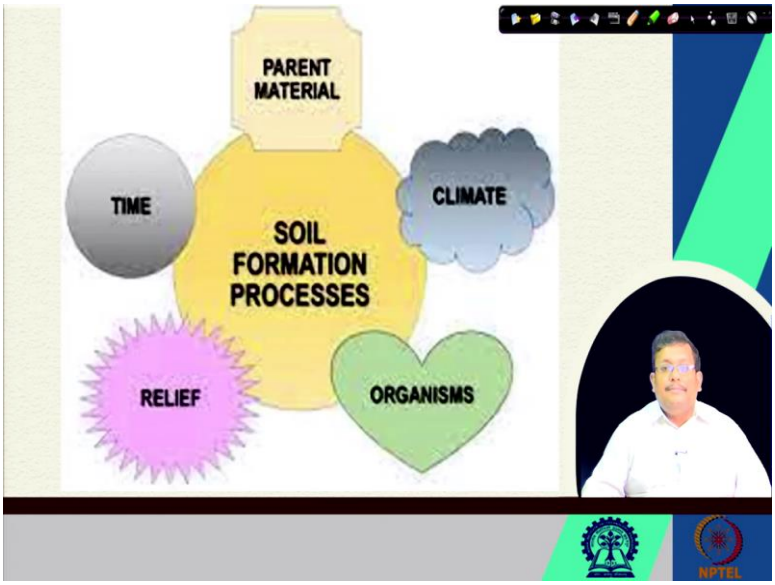

Now, we know all that the soil formation process if we remember the Genie's soil formation theory, we can see that soil formation is a function of relief, time, parent material climate and different types of organisms. Now, of course, there has been several modifications from this, but this is the fundamental concept of soil formation. And from there, we can have an idea about how these different important parameters are controlling the soil formation.

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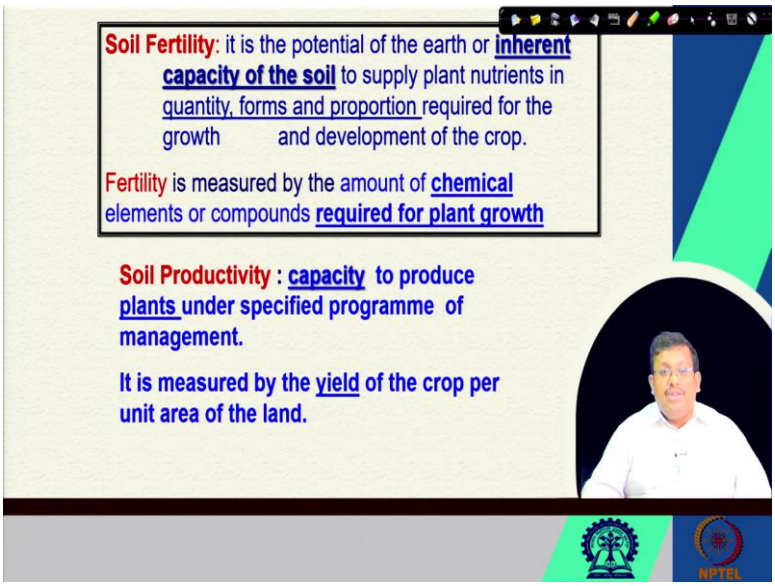

Now, let us see what is the definition of soil fertility? Soil fertility it is the potential of the earth or inherited capacity of the soil to supply plant nutrients in quantity, forms and proportion required for the growth and development of the crop. Now, remember that here I have underlined one important term that is inherent capacity of the soil.

So, fertility is measured by the amount of chemical elements or compound required for the plant growth. But this definition of the soil fertility differs from soil productivity which terms which is basically the soil productivity is basically the capacity to produce the plants under specified program of management. Now, it is measured by the yield of the crop per unit area of the land. Remember, there is a stark difference between soil fertility and soil productivity.

A soil may be fertile, but it may or may not be productive because here the productivity is solely dependent on the produce. So, although some soils are inherent, same some soils may have high inherent capacity to supply the nutrients and required quantities to the plant, they may not produce the required quantity of the output or yield of the crop due to different types of factors. So, that is why soil fertility and soil productivity are not same, they differ from each other.

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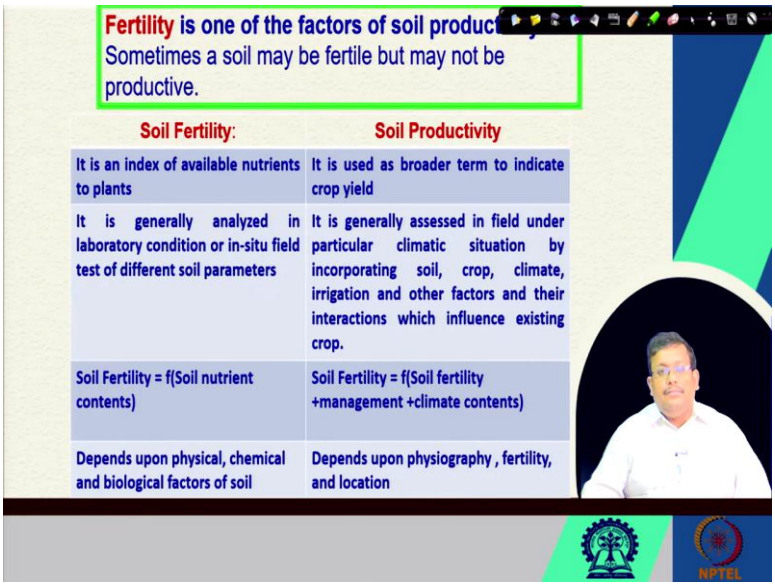

Now, fertility is one of the factors of soil production and sometimes a soil may be fertile but may not be productive just like I have said in our previous slide. Now, this shows this table shows the clear difference between the soil fertility and productivity then you can see that soil fertility is an index of available nutrients of the plants.

However, soil productivity is used as a broader term to indicate the crop yield. It is soil fertility is generally analyzed in laboratory condition or in-situ field test of different soil parameters and soil productivity it is generally assessed in field under particular climatic situation by incorporating soil, crop, climate, irrigation and other factors and their interaction which influence existing crop.

So, not only here in soil productivity, we are concerned about soil, but there is a mixed interplay between the climate, irrigation and crop and soil these factors they interact with each other to finally get the produce, so, that defines soil productivity. Of course, soil fertility is the function of soil nutrient content whereas, soil fertility is the function of soil fertility plus management plus climate contents.

Remember that the soil fertility depends on soil, physical, chemical and biological properties. However, in case of soil for productivity, it depends on physiography, fertility and location of the soil. Now, I hope that it is clear what is the difference between soil fertility and productivity.

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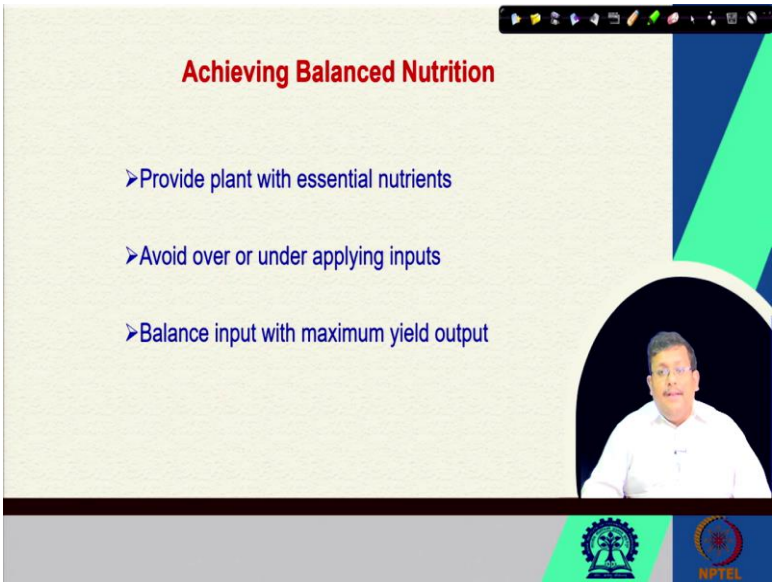

So, this is important from this point of view of soil fertility it is very very important to achieve a balanced nutrition because if we do not get balanced nutrition, our soil cannot be productive. So, how to achieve this balanced nutrition, there are three important steps for achieving this balanced nutrition first of all to provide plants with essential nutrients.

Secondly, to avoid over or under applying the nutrients, we should not apply too much of a nutrient that can create nutrient toxicity or we should not apply too little amount of nutrient that can create the soil nutrient deficiency and of course, we have to balance our input with maximum yield output. So, these are the three major pillars of achieving the balanced nutrition for the plant.

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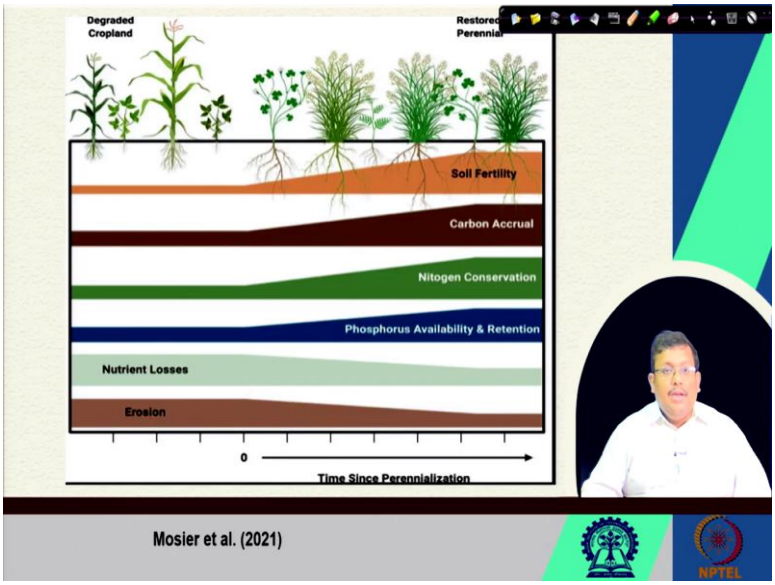

Now, if you see these, this diagram, it is quite clear that as we go from degraded cropland to restored perennial land, so, if we can go from these rest degraded cropland to restored perennial crops, we can clearly increase the soil fertility, we can clearly increase the carbon accrued or accrual and we can also increase the nitrogen conservation.

Of course, that also simultaneously increase phosphorus availability and retention. So, you can see all the beneficial factors for improving the soil faculty fertility improves. So, phosphorus availability and retention improves, nitrogen conservation improves and also carbon accrual is also improves. Of course, the nitrogen conservation is interrelated with carbon accrual and ultimately all these three important factors influence in the augmentation of soil fertility.

However, on opposite, the nutrient losses will be decreased substantially and also erosion of soil will also decrease substantially. So, these are the important factors, which you can see when we go from growing crops in the degraded crop lands to restore perennial, when we change the crop to with the perennial crops. So, that shows the importance of changing your practice for improving the soil fertility.

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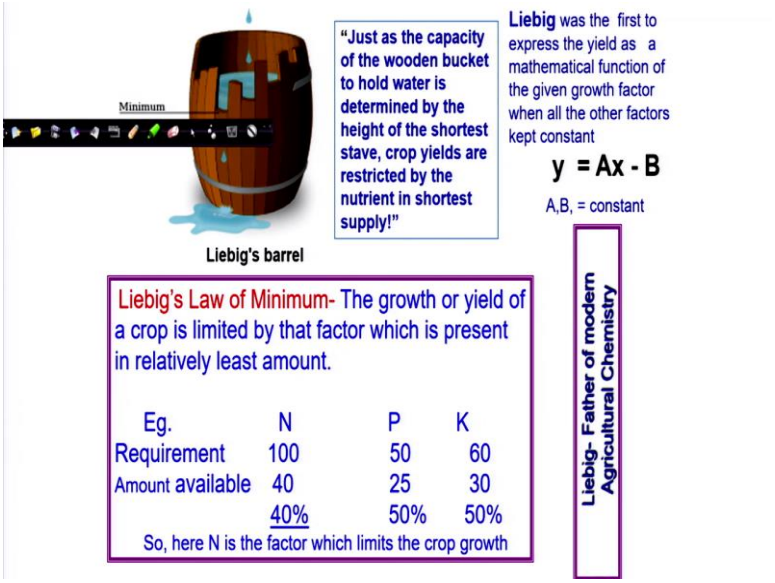

Now, next another important concept let me just drag it here. So, another important concept is concept is Liebig's Law of Minimum, now, what is Liebig's law of minimum? Liebig's law of minimum says just as the capacity you can see this above is a barrel, so, our bucket you can consider it as an bucket.

So, just as the capacity of the wooden bucket to hold water is determined by the end of the shortest stave, crop yields are also restricted by the nutrients in shortest supply. So, you can see here in this barrel, these minimum, of the shortest stave is determining the level of water. So, the level of water will be up to this height it cannot go beyond. So, Liebig's law of minimum also says that the crop yields are restricted by the nutrients in shortest supply.

So, here just one example, so, Liebig's law of minimum says that the growth or yield of a crop is limited by the factor which is present in relatively least amount. So, here you can see suppose, for growing a crop, the requirement is nitrogen 100 and phosphorus is 50 and potassium is 60 and the available amount of nutrient is 40, phosphorus is 25 and potassium is 30. So, we can see only 40 percent of nitrogen is available, 50 percent of phosphorus is available and 50 percent of potassium is available.

So, here nitrogen is a factor which limits the crop growth because it is the least the nutrient which has the shortest supply. So, Liebig was the first to express the yield as a mathematical function of the given growth factor when all the other factors keep constant. So, here y equal to Ax minus B where A and B are constant. So, Liebig is also known as the father of modern agricultural chemistry.

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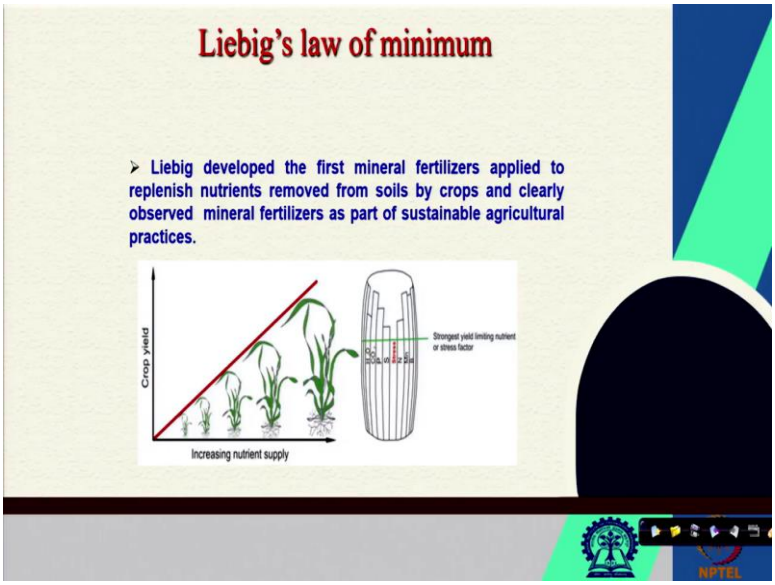

So, what is Liebig's law of minimum? So, Liebig developed the first mineral fertilizer applied to replenish the nutrients removed from soil by crops and clearly observed mineral fertilizers as part of sustainable agricultural practices. So, here you can see as we increase the nutrient supply, the crop yield will really increase however the growth of the crop will be determined by the list available factor. So, here you can see the strongest limiting us or a stress factor will be determined by the list limit among the most limiting nutrient.

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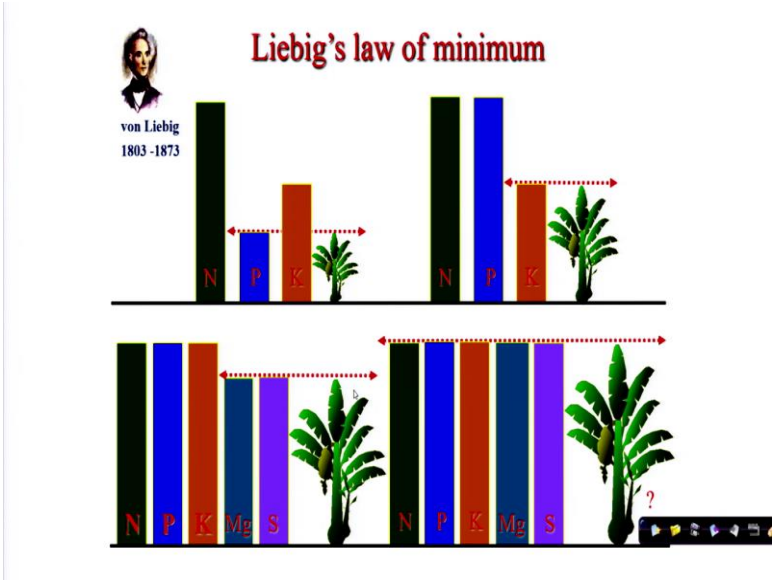

So, if we go to Olympics law of minimum, some more examples you can see here in this example, we have nitrogen, phosphorus, potassium, but phosphorus is the least available

nutrient. So, the growth of the crop will be determined by phosphorus only. Another example is here, where potassium is the nutrient with the shortest supply.

So, the crop growth will be based on this potassium. Here you can see that magnesium and sulphur are two limited nutrients. So, of course, these two will govern the crop growth. And however, here you can see, all these are in the same, all these nutrients are in the same quality of supply.

So, it is quite clear. So, in this case of course, they all they are governing the with the growth of the plant. However, from here we can see that phosphorus potassium and magnesium sulphur and influencing or controlling the growth of the crop because they are the minimum, they are the nutrients which has the shortest supply. So, this is the Liebig's law of minimum.

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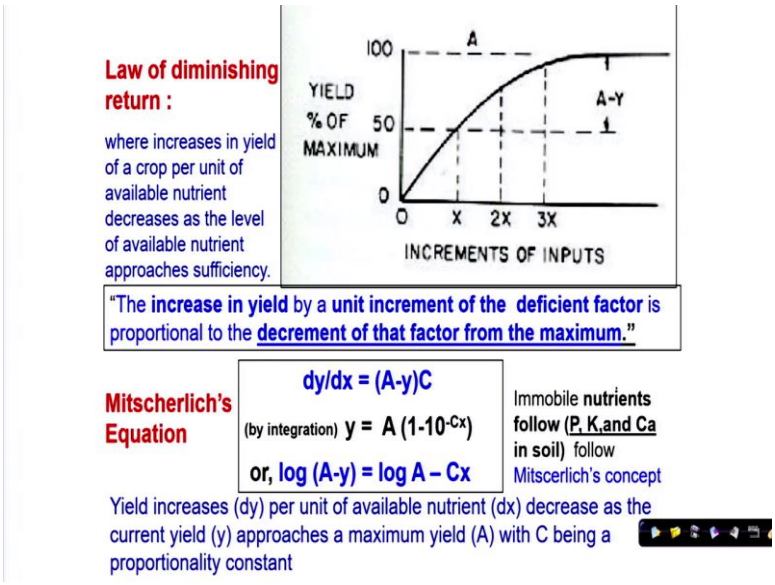

So, another important term is law of diminishing return. Now, law of diminishing returns says when increase in yield of a crop per unit of available nutrient decreases as the level of available nutrient approaches sufficiency. In other words, the increase in yield by a unit increment of the deficient factor is proportional to the decrement of that factor from the maximum.

So, here you can see, when we are increasing the inputs lies from 0 to x, then 2x to 3x, and here in the y axis, we can see the yield percentage of maximum. So, you can see 50 percent growth and 50 percent yield, 100 percent yield, you can see four unit increase of inputs from x to 2x and from 2x to 3x, the difference of or the yield increase is getting decreased.

So, the increase in yield by unit increment of the deficient factor suppose this x is a deficient factor is proportional to the decrement of the factor from the maximum. So, that shows that this is called the law of diminishing return that means, we are increasing the inputs, but our return is diminishing.

So, this is this can be mathematically expressed by Mitscherlich's equation, which is dy by dx equal to A minus y into C, by integration, we can see y equal to A into 1 minus 10 to the power minus Cx, or if you take the log, so log of Ay equal to log of A minus Cx. Remember that in this here, in this equation, this dy is the yield increase per unit available nutrient that is dx.

So, dy by dx decreases as the current yield, which is supposed y approaches a maximum yield. So here A is the maximum yield. So, as our yield is approaching this maximum A, with C being a proportionality constant, the dy by dx is getting decreased. So, this is the Mitscherlich's equation. Again, as we are approaching towards the highest possible yield that is A, we are getting decreasing yield per unit increase of inputs. So, this is called the Mitscherlich equation.

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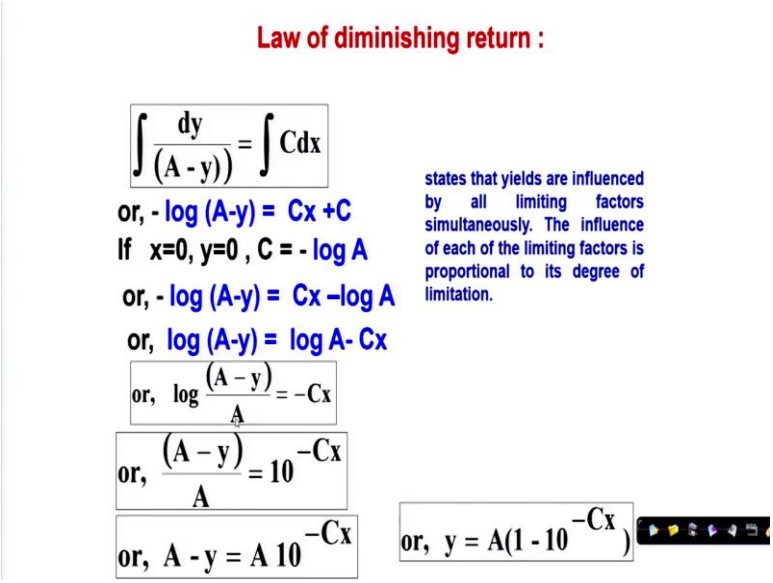

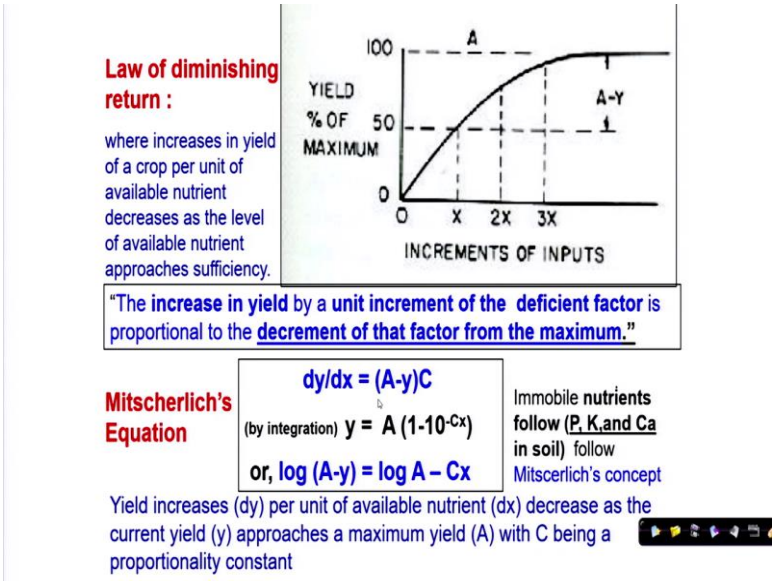

Now, this is the mathematical derivation, you can see dy A minus y and if we take the integration the both sides will get this simplification minus from here we will get minus log of A minus y equal to Cx plus C or if x is equal to 0, y equal to 0 and C equal to minus log A, we can see that minus log A minus y equal to Cx minus log A or we can simplify it to ultimately y equal to A into 1 minus 10 to the power minus Cx.

So, it states that yields are influenced by all limiting factors simultaneously, the influence of each of the limiting factor is proportional to its degree of limitation. So, this is the ultimate mathematical equation, which we have seen previously. So, this is how we get this equation, we derive this equation.

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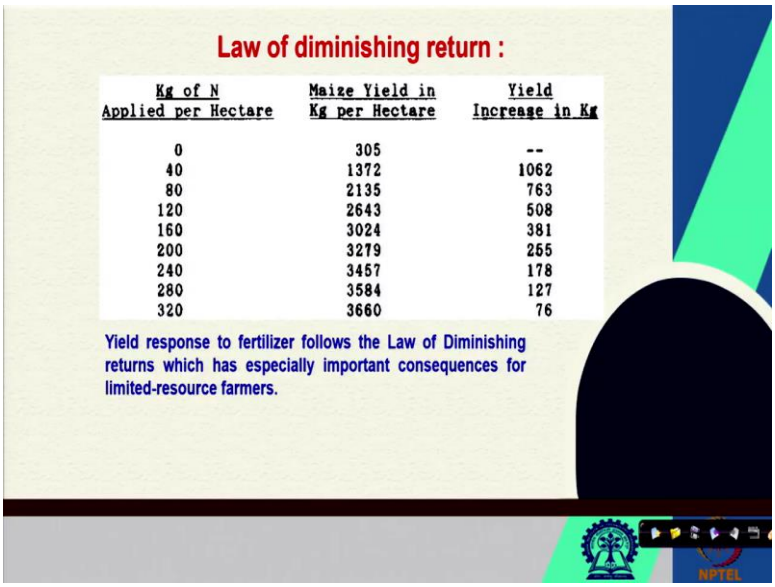

So, if we see the law of diminishing return, of course, here you can see that kg of nitrogen applied per hectare as increased from 0, 40, 80, 120, 160, 200, 240, 280, 320. Unit increase from 40 kg you can see here we can see maize yield in kg per hectare, it is 305, 1372, 2135, 2643. So, you can see that yield increase in kg getting diminished as we continue to increase our inputs.

So, here we continue to increase our inputs from 0 to 40 to 80 to 120 to up to 220 however, the yield increase in kg you can see here it is continuously getting decrease. So, yield response to fertilizer follows the law of diminishing returns which has especially important consequences for limited resources farmers. So, limit resource farmers, you can clearly see that with the increase of their input, how much increase in yield they will get. So that shows the importance of input especially for the limited-resource farmers.

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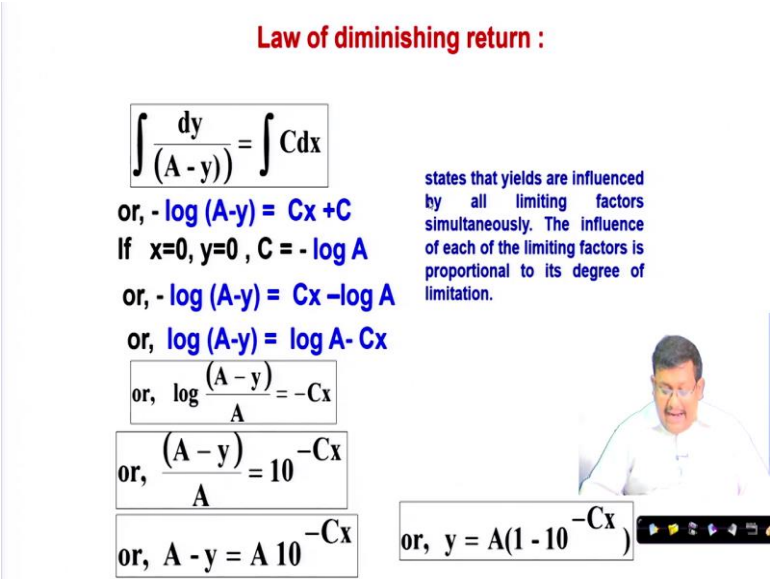

Another important term that immobile nutrients generally phosphorus, potassium, calcium follow generally the Mitscherlich's concept this is important to remember.

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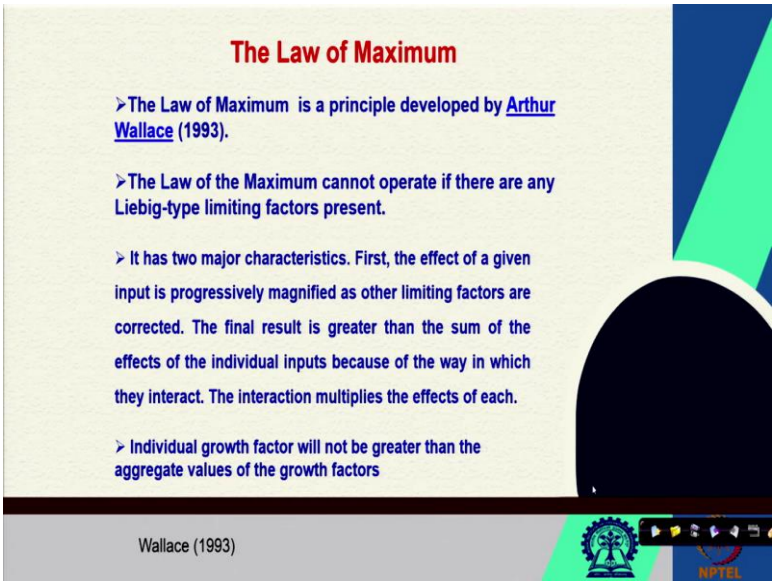

And also there is another law that is called the law of maximum. This law of maximum is a principle developed by Arthur Wallace and the law of maximum cannot operate if there are any Liebig type limiting factors present. So, it has two major characteristics, first the effect of a given input is progressively magnified as other limiting factors are corrected.

The final result is greater than the sum of the effects of the individual inputs, because of the way in which they interact and the interaction multiplies the effect of each. So, here individual growth factor will not be greater than the aggregate values of the growth factors. So, guys, we have defined in this class so far, what is soil and why it is important, why it is important to maintain the soil, we have also seen, what is soil health, what are the important factors that controls the soil health, what are the indicators of the soil health.

Then, we have seen what is the Liebig's law of minimum, we have seen the law of diminishing return and also we have seen the law of maximum. So, let us wrap up our lecture here and will go from here in our next class, and will discuss more about this the law of maximum. So, I wish you I wish you have learned something new. And if you have any question, please feel free to post it in the forum. And we will be more than happy to answer your queries. Thank you very much.