Soil Fertility and Fertilizers
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Lecture 47
Biofertilizers and Management of Fertilizers and Manures in Soil (Contd.)

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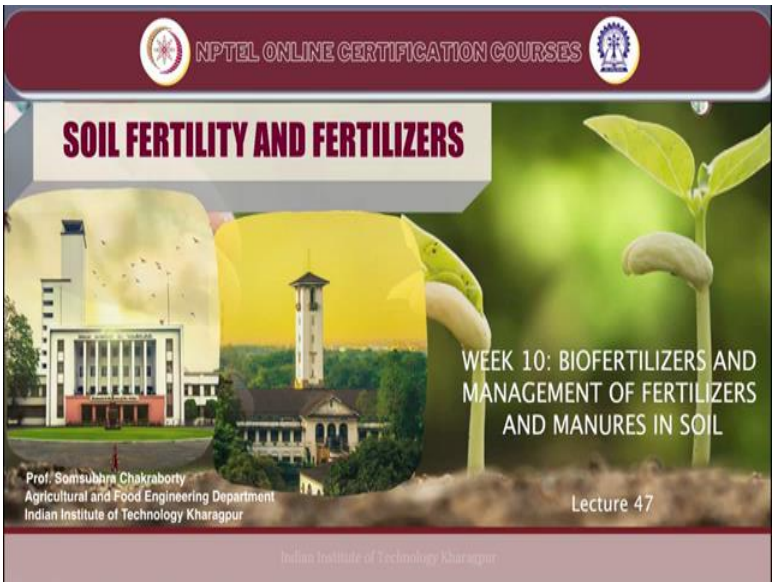

Welcome friends to this 47th lecture of NPTEL online certification course of Soil Fertility and Fertilizers. And in this week, we are discussing about Biofertilizers and Management of Fertilizers and Manures in Soil.

In the first lecture, we have already discussed about the biofertilizers and what the definition of the biofertilizer, types of biofertilizers, we have discussed about symbiotic relationship between legume as well as rhizobium and how rhizobium can help in enhancing the environmental and also environmental safety and also agriculture sustainability we have discussed.

We have discussed other aspects like phosphate solubilizing microorganisms, how to grow them in mass culture we have discussed, we have also discussed azotobacter or free living microorganisms, we have discussed about azospirillum, we have discussed about cyanobacteria and how they can help in fixing the atmospheric nitrogen we have discussed. We have also discussed the mycorrhizal relationship, classification of the mycorrhizae and how to mass produce this mycorrhizae for inoculation we have also discussed.

So, now we have got some good knowledge about mycorrhizal association and biofertilizers and their application, let us discuss another very important concept as far as the soil fertility

and improvement of soil physiochemical properties are concerned. This is Biochar, so in this lecture we are going to focus on Biochar.

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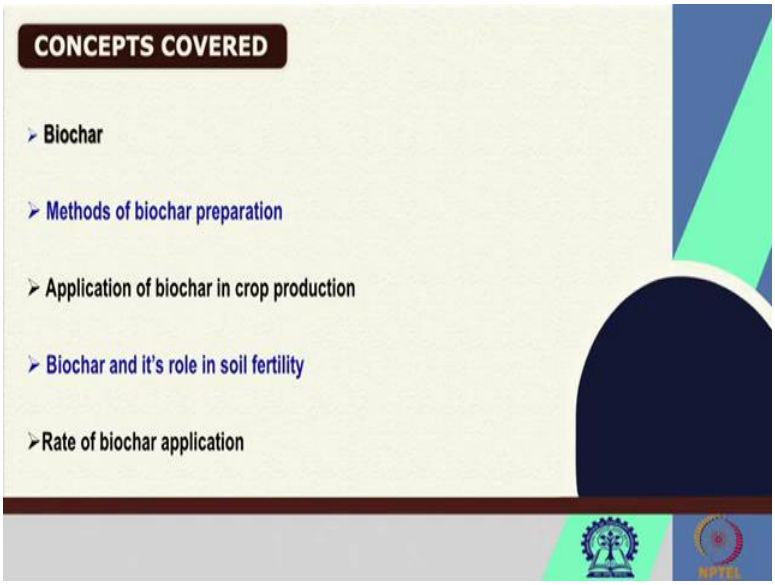

Now, these are the concepts which we are going to cover in this lecture. First of all, we are going to discuss what is Biochar and then we are going to discuss the methods of biochar preparation, then we are going to discuss the application of biochar in crop production and then we are going to also discuss biochar and its role in soil fertility and rate of biochar application. So, these are and apart from that we are also going to see some case studies where biochar application has shown the beneficial effect in plant growth. So, these will be the topics for or the concepts which we are going to cover in this lecture.

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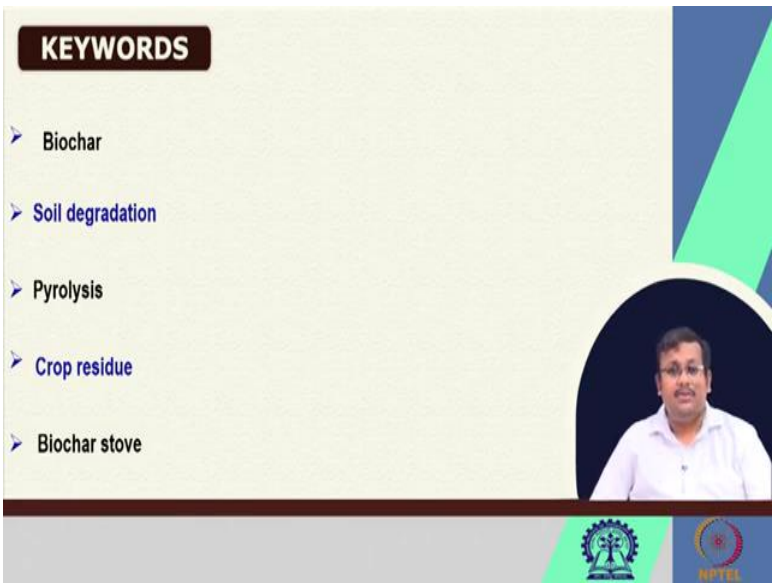

These are the keywords, biochar, soil degradation, pyrolysis, crop residue and biochar stove. So, these are some of the keywords for this lecture.

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Now, biochar is an important component of soil enhancing the soil fertility and crop growth and there are numerous research in the application and development and application of biochar for enhancing the soil fertility worldwide.

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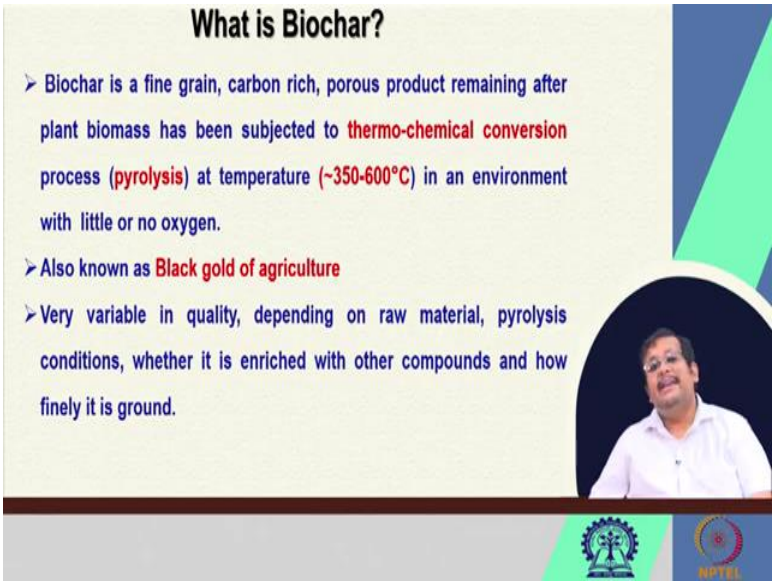

Now, the question comes what is biochar? So, biochar is a fine grain, carbon rich, porous product remaining after plant biomass has been subjected to thermochemical conversion process, we call it pyrolysis at temperature around 350 to 600 degree centigrade in an environment with little or no oxygen.

So, basically in an anaerobic condition when plant biomass is converted into the carbon rich porous product that carbon rich porous product is known as biochar and the conversion is known as thermo chemical conversion, remember that these biochar is also known as black gold of agriculture and it varies based on quality depending on raw material, pyrolysis condition, whether it is enriched with other compounds and how finely it is ground. So, all these are important factors to determine the biochar quality.

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Now, long term intensive cultivation of soil results in soil degradation, we know that also we also know that long term intensive cultivation can decrease the soil fertility and at the same time they can increase the soil erosion, which are the major concern in global agriculture. Now, the decrease in soil organic matter decreases the aggregate stability of the soil, because we know that soil organic matter helps in aggregate stability.

Now, when there is a loss of soil organic matter that subsequently help that subsequently creates the loss in aggregate stability of the soil, therefore it is crucial to remediate the soil degradation by incorporation of organic materials, unless we replenish the soil by application of organic materials that ecosystem function of the soil cannot be revived.

Moreover, biochar is remember that this compound biochar this compound this product biochar is rich in nitrate and phosphate could be also proposed to be a slow release fertilizer to enhance the soil fertility. So, not only it enhance the carbon content on the soil but also it acts as a slow release fertilizer to enhance the soil fertility.

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Now, manures and compost that both lead to ammonium and methane release which can aggravate the global warming, because ammonia I mean the methane is a greenhouse gas and they can aggravate the global warming and groundwater pollution and also cause long term contamination of farmland due to presence of pathogens, heavy metals and pharmaceuticals.

Now, biochar is a renewable resource, so being a renewable resource biochar is promising resource for soils fertility management due to its economic and environmental benefit. So, what are the economic and environmental benefits we are going to discuss in our subsequent slides.

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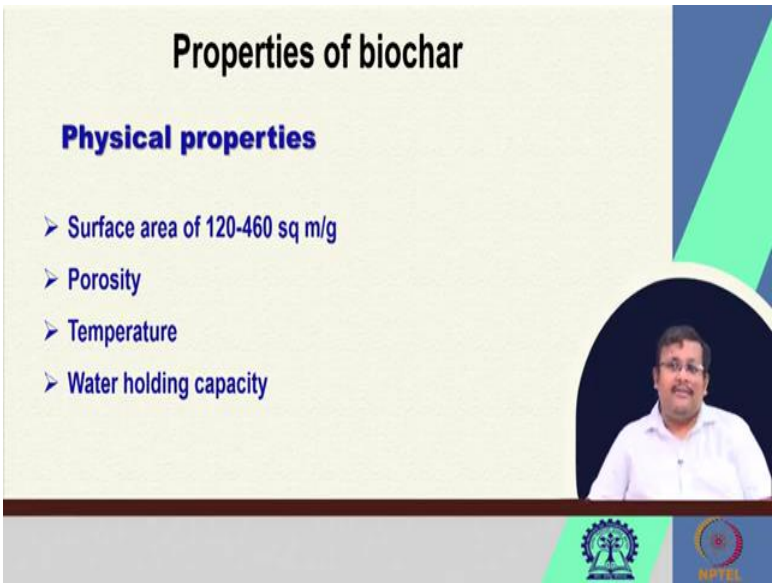

Now, let us see the properties of the biofertilizer. So, the physical, now we know that both manures and compost they lead to the release of ammonium and ammonia and methane which can aggravate the global warming and groundwater pollution and also cause long-term contamination of farmland due to presence of pathogens heavy metals and pharmaceuticals.

Now, being a renewable biochar is a renewable resources resource. So, being a renewable resource biochar is promising resource for soils fertility management due to its economic and environmental benefits.

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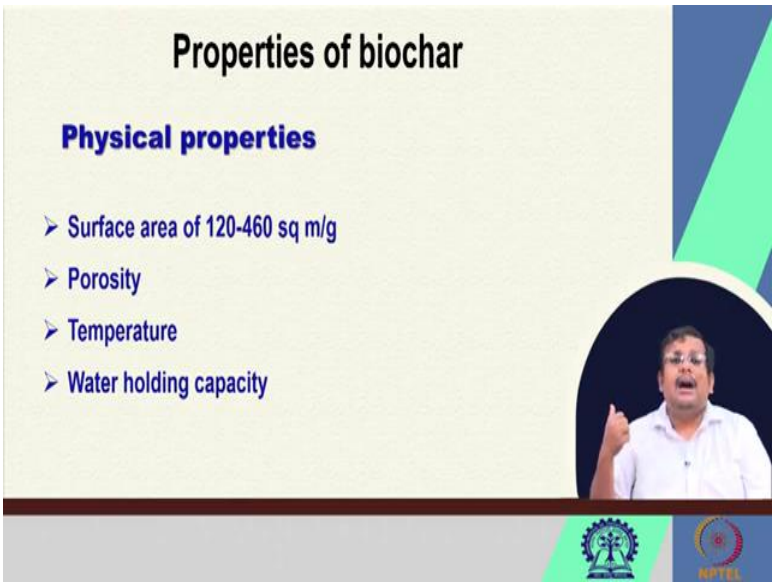

Now, let us see what are the physical properties of biochar? So, surface area as far as the surface area of the biochar, 1 gram of biochar can produce and surface area of 120 to 460 square meter of surface area, it is highly porous and it helps in stabilizing the temperature and

also it can help in increasing the water holding capacity. So, once we apply the biofertilizer, since it is porous, it increases the porosity and it enhance the temperature stability and it basically reduce the temperature and also it can enhance the water holding capacity.

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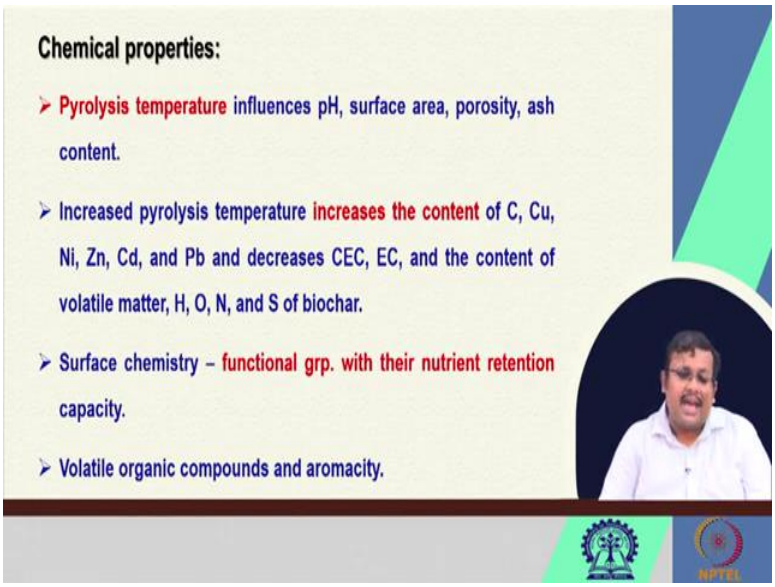

Now, as far as the chemical properties are concerned pyrolysis temperature influences pH, surface area, porosity and ash content. Now, increased pyrolysis temperature increases the content of carbon, copper, nickel, zinc, and cadmium and lead and decreases carbo cation action capacity, electrical conductivity and the content of volatile matter and H, O, N, and sulphur of biochar.

Now, surface as far as the surface chemistry of biochar is concerned, now functional groups with the nutrient retention capacity helps in helps in enhancing the soil fertility and also these biochar has volatile organic compounds and produces aromatic also they have biochar has the aromatic compounds.

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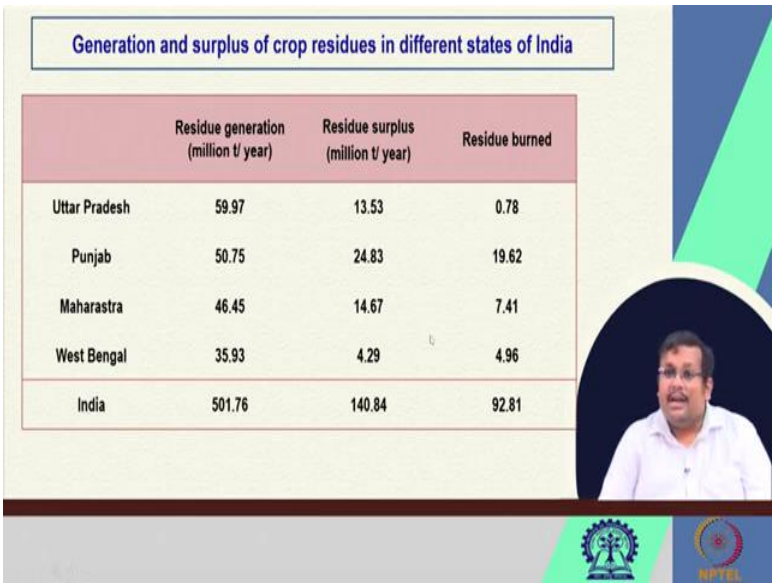

Now, let us see the generation and surplus of crop residues in different states of India, if we see how we can create this biochar in Indian condition of course we can see that all the steps all the different states can produce huge amount of surplus residue. For example, in Uttar Pradesh, we can see the surplus residue of 13.53 million ton per year, so and also residue born is 0.78 million tons.

And you can see in Punjab residue generation is 50.75 million ton per year and residue surplus is 24.83 million ton among these 19.62 million tons we are burning. And also in Maharashtra also we can see 7.41 million 10 per year is burn and in West Bengal 4.496 million tons in burned. So, in India total 92.81 million tons of residues are burned each and every year which are surplus and which could be converted into the biochar.

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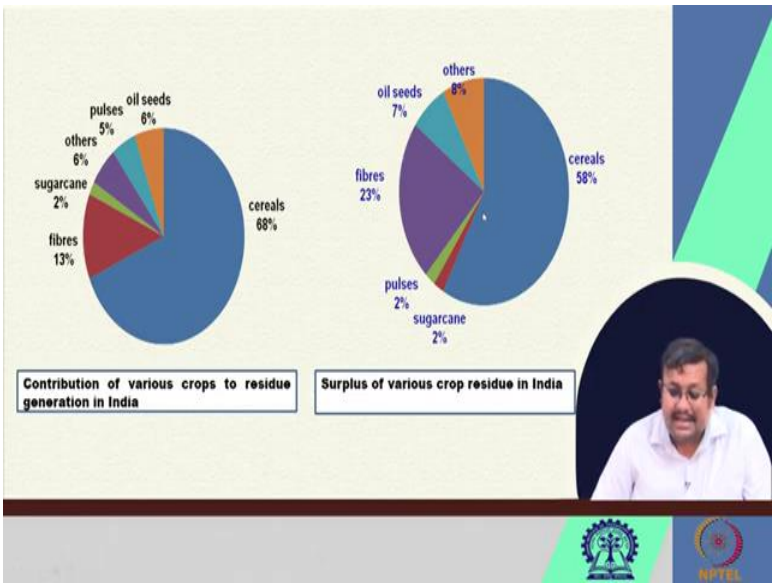

Now, if you see the contribution of various crops to residue generation India of course cereals helps in generating the maximum residue in India and also the surplus of the various crop residue we can see cereals has a majority of the surplus of the residues which are produced in India. So, all these can be utilized for creation of biochar.

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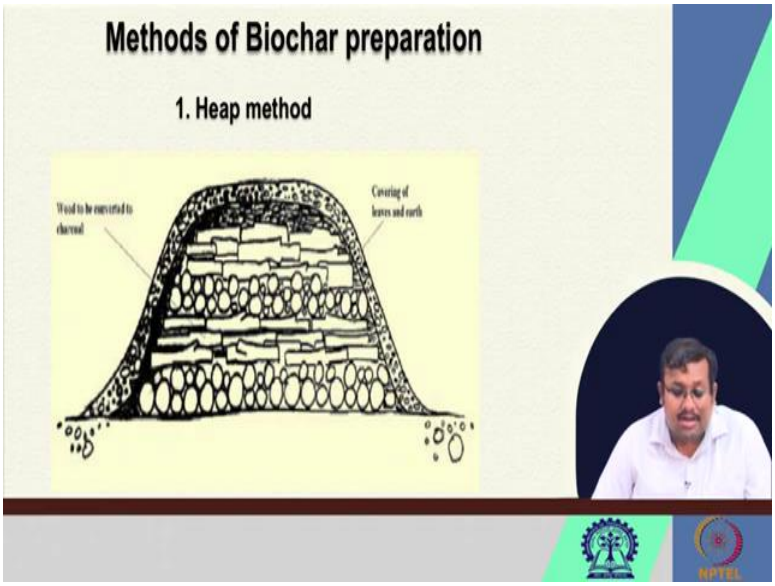

Now, there are 3 methods of biochar, one the heap method and in the heap method wood can be converted into charcoal, you can see here and here we covered this wood with leaves and earth in this heap method of biochar preparation.

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The second method is known as the drum method you can see the pictures of drum method preparation of biochar.

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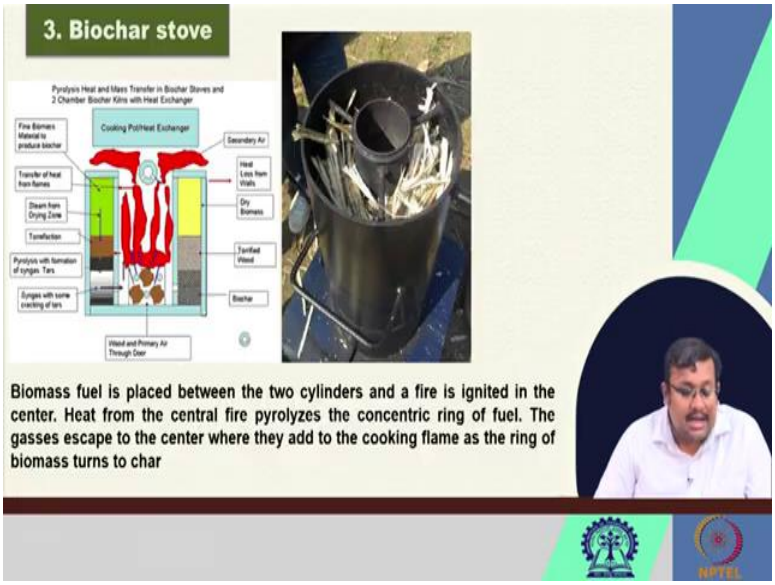

And the third method is biogas, biochar stove method. Now, this is the internal structure of the biochar stove and this is the actual biochar stove. So, in this biochar stove basically biomass fuel is placed between the 2 cylinders so you can see here there are 2 cylinder, one cylinder and second cylinder. So, the biomass material is placed between the 2 cylinders and a fire is ignited in the center. So, we pack the biomass in between the 2 cylinders and the fire is ignited in the center.

Now, heat from the center, heat from the central fire pyrolyzes the concentrated ring of fuel, so this fuel are being pyrolyzed by the heat which is generated by this fire and the gases basically syngas which escape to the center. So, you can see there are connections, so the syngas can escape to the center where they add to the cooking flame as the, as a ring of the biomass turns into char.

So, here these biomass are pyrolyzed and basically they are converted into biochar while the gas which are prepared, which are produced during the pyrolysis they can help, they can escape into the center and they can help in the ignition process. So, this is the biochar stove and this is how biochar is produced.

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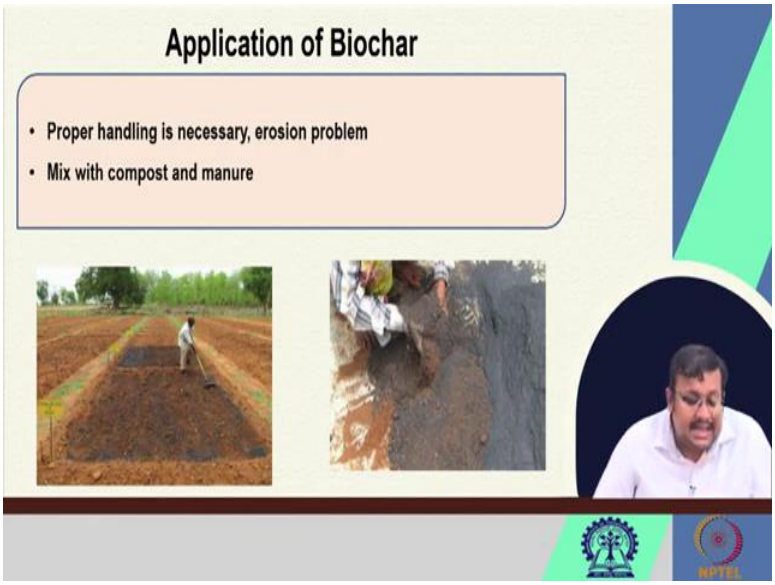

Now, application of biochar remember that proper handling of biochar is necessary because there might be some erosion problem and generally we apply this biochar with mix, after mixing it with the compost and manure. So, biochar is generally applied to the soil after mixing it with compost and manure as you can see they are mixed with compost and manure and then they apply to the field.

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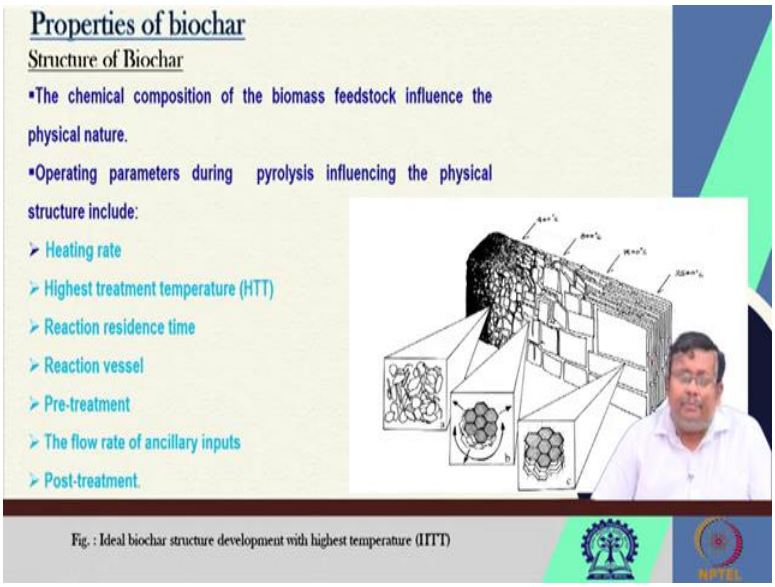

Now, let us see the detailed properties of biochar, let us see the structure of the biochar, the chemical composition of biomass feedstock influence the physical influence the physical nature. Now, let us see the details properties of biochar, if we see the structure of the biochar first of all the chemical composition of the biomass feedstock influences the physical nature.

So, basically what we are using as a feedstock that influence the quality of the biochar and operating parameters during pyrolysis which are influencing we generally influence the physical structures they are basically heating rate, then highest treatment temperature, then reaction residence time, then reaction vessel, then pre-treatment, then the flow rate of the ancillary inputs and finally the post treatment. So, all these are important factors which cons, which basically governs the physical structure of the biochar.

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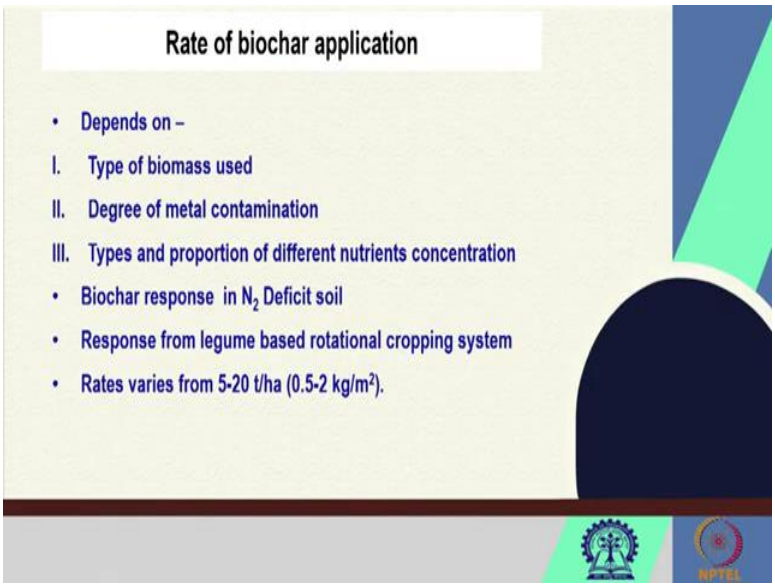

Now, rate of biochar generally depends on type of biomass used and then degree of metal contamination and then types and proportion of different nutrients concentration. So, basically biochar gives good response in nitrogen deficit soil and it also we can have good response from legume-based rotational cropping system and the rates of application generally varies from 5 to 20 tons per hectare or 0.5 to 2 kg per square meter, this should be the rate of biochar application.

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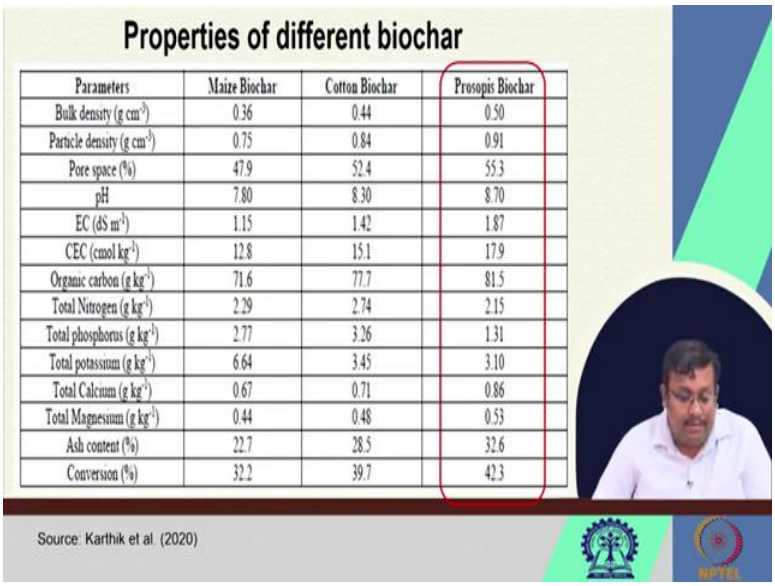

Parameters	Maize Biochar	Cotton Biochar	Prosopis Biochar
Bulk density (g cm^{-3})	0.36	0.44	0.50
Particle density (g cm^{-3})	0.75	0.84	0.91
Pore space (%)	47.9	52.4	55.3
pH	7.80	8.30	8.70
EC (dS m^{-1})	1.15	1.42	1.87
CEC (cmol kg^{-1})	12.8	15.1	17.9
Organic carbon (g kg^{-1})	71.6	77.7	81.5
Total Nitrogen (g kg^{-1})	2.29	2.74	2.15
Total phosphorus (g kg^{-1})	2.77	3.26	1.31
Total potassium (g kg^{-1})	6.64	3.45	3.10
Total Calcium (g kg^{-1})	0.67	0.71	0.86
Total Magnesium (g kg^{-1})	0.44	0.48	0.53
Ash content (%)	22.7	28.5	32.6
Conversion (%)	32.2	39.7	42.3

Now, if we see the properties of different bio char you can see maize biochar, cotton biochar and prosopis biochar, we can see the maize biochar has the lowest bulk density, the particle density is highest in case of prosopis biochar, the pore space or porosity is basically highest

in case of prosopis biochar, pH is towards a neutral in case of maize biochar, however, they, the cotton biochar and prosopis biochar are having the alkaline phH.

Electrical conductivity are low in all three, then cation action capacity is highest in case of prosopis biochar, organic carbon is highest in case of prosopis, total nitrogen is highest in case of cotton biochar, total phosphorus is highest in case of cotton biochar, total potassium is highest in case of maize biochar, total calcium is highest in case of prosopis biochar, total magnesium is highest in case of prosopis biochar, ash content is highest in case of prosopis biochar and conversion is basically highest in case of prosopis.

So, basically depends on you can see that the properties are depending on the type of feedstock which you are adding into the, which we are using for preparation of the, preparation of the biochar.

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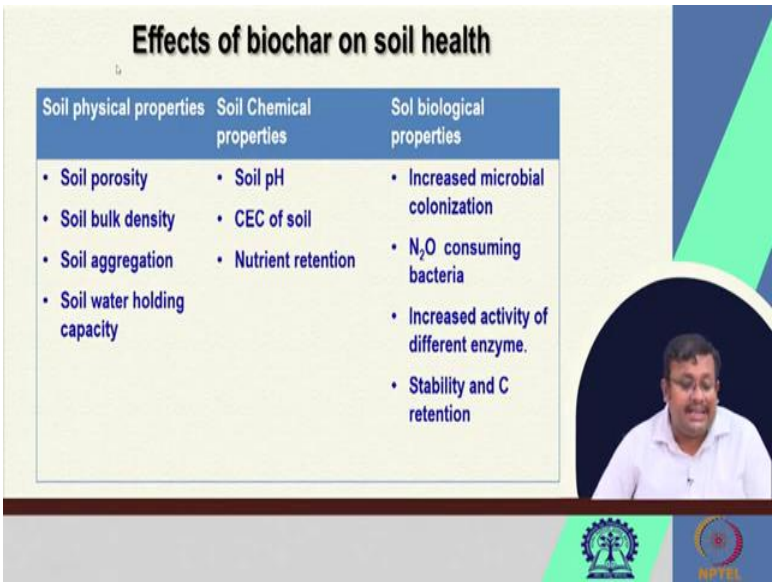

Now, what are the effects of biochar on soil health? Basically it helps in as far as the soil proper, physical properties are concerned it increases the soil porosity, it decreases the soil bulk density, it enhance the soil aggregation and it enhance the soil water holding capacity, it stabilizes the soil pH, it enhances the cation action capacity of the soil and it helps in nutrient retention.

As far as the biological properties are concerned, it increase the microbial colonization, it increase in, it helps in the increase of nitrous oxide, consuming (())(18:50) nitrous oxide is an important greenhouse gas. So, it helps in soil biological properties.

Now, let us see the effects of biochar on soil health. So, we can see the soil physical as far as the soil physical properties are concerned it increases the soil porosity, it decreases soil bulk density, at it enhances the soil aggregation and it decree, and also it enhances the soil water holding capacity, its biochar stabilizes soil pH increases cotton action capacity and enhances the nutrient retention.

Soil biological properties, I mean it increases the microbial colonization, increases the nitrous oxide consuming bacteria thereby reducing these greenhouse gas and also increase the activity of different enzymes and also it helps in stability and carbon retention. So, these are the beneficial effects of biochar.

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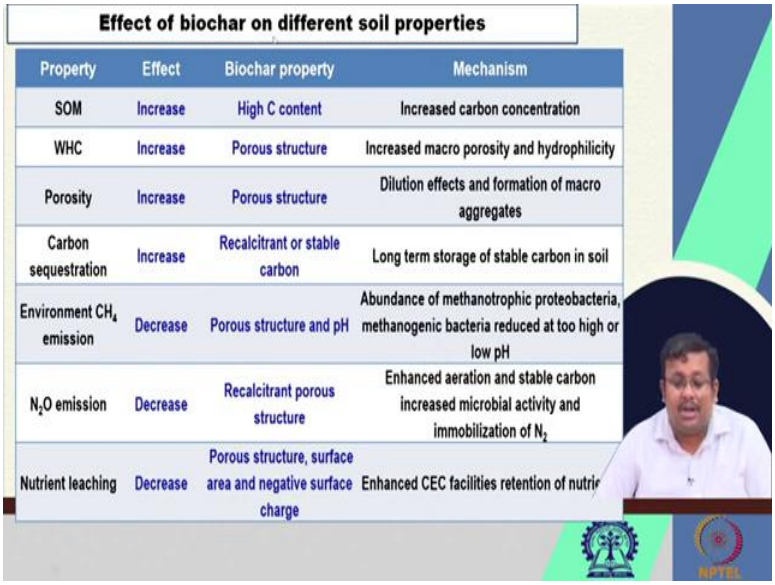

Now, we can see effects of biochar on different soil properties you can see it can enhance the soil organic matter because biochar has high carbon content and it increase carbon concentration. It increase the water holding capacity because it has porous status and because and the mechanism involved is increased macro porosity and hydrophilicity.

It increases the porosity because it has also porous structure so dilution effects and formation of macro aggregates. And then it helps in increasing the carbon sequestration because it helps in long term storage of stable carbon in soil and if the property is recalcitrant or stable carbon it decrease the environmental methane emission because abundance of methanotrophic proteobacteria methanogenic bacteria also reduce at too high or low pH.

So, basically they helps in reducing the environmental methane emission, they decrease the nitrous oxide emission by producing this enhanced aeration and stable carbon, it enhances the

microbial activity and immobilization of nitrogen and also they decrease the nutrient leaching because they have enhanced, they have high cation action capacity and they can retain the nutrients.

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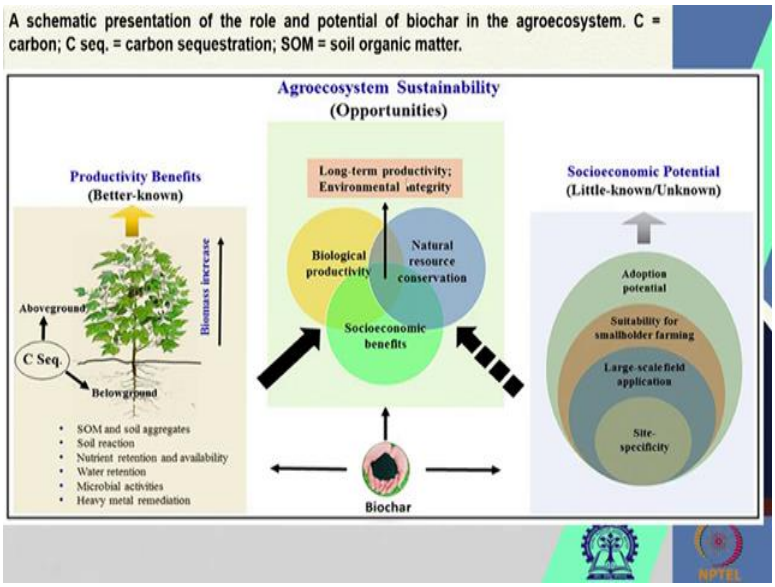

So, if you see the simatic presentation showing the role and potential of biochar in the agroecosystem. So, you can see there are several opportunities, so productivity benefits you can see it can enhance the biomass and also it can enhance the carbon sequestration so it enhance the soil oraganic matter and soil aggregate, soil, it stabilizes the soil reaction, it helps in augmenting the soil nutrient retention and availability and water retention, microbial activities and heavy metal remediation.

So, all these are beneficial effects for biochar for as far as the productivity is concerned and also from the socioeconomic point of view also we have the site specificity and large scale field application and suitability for smallholder farming and adoption potential. So, we can see that these can also help in natural resource conservation and biochar can also helps in biological productivity, enhancing the biological productivity and those to help in socioeconomic benefits.

So, biochar can not only improve the productivity and other factors of soil but also socioeconomic involvement, also socioeconomic potential of biochar is also quite high. So, both this socio-economic potential and also productivity potential can help in maintaining the biological productivity, natural resource conservation and as a whole socio-economic benefits. So, finally it will all boil down into long-term increasing, the long-term productivity

and also environmental integrity. So, the agrosystem sustainability can be enhanced by application of biochar.

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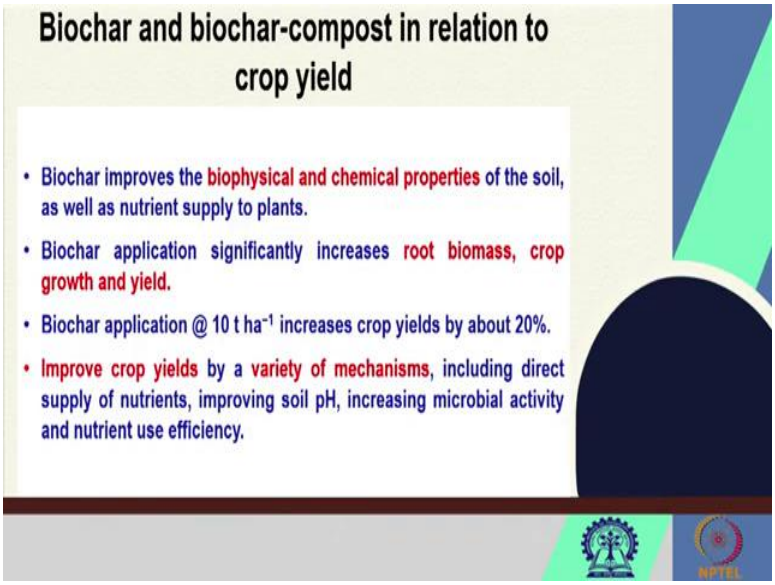

Now, let us see the biochar and biochar compost in relation to crop yield. So, biochar improves the biophysical and chemical properties of the soil as well as nutrient supply to plants. And biochar applications significantly increases root biomass, crop growth and yield and biochar application at 10 ton per hectare, increases crop yield by about 20 percent and it improve crop yields by a variety of mechanisms including direct supply of nutrients, improving soil pH, increasing microbial activity and nutrient use efficiency.

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Treatments	Plant height (cm)	Root nodules (Nos)	Dry matter (kg ha^{-1})	Pod yield (kg ha^{-1})	100 seed weight (g)
Control	27.8^{c}	81^{c}	1659^{c}	1281^{c}	24.4^{e}
Arbuscular mycorrhizae 100 kg ha^{-1}	29.7^{b}	94^{b}	1907^{b}	1418^{b}	27.4^{d}
Composted coir pith 10 t ha^{-1}	32.6^{ab}	108^{a}	2040^{ab}	1599^{ab}	30.0^{ab}
Enriched farmyard manure 0.75 t ha^{-1}	29.1^{b}	88^{b}	1838^{b}	1425^{b}	26.8^{d}
Maize stalk biochar 2.5 t ha^{-1}	30.2^{b}	93^{b}	1970^{ab}	1528^{ab}	28.0^{c}
Maize stalk biochar 5 t ha^{-1}	**34.4^{ab}**	**105^{ab}**	**2137^{ab}**	**1644^{ab}**	**31.0^{a}**
Cotton stalk biochar 2.5 t ha^{-1}	31.3^{b}	91^{b}	1843^{b}	1536^{ab}	28.3^{c}
Cotton stalk biochar 5 t ha^{-1}	33.2^{ab}	102^{ab}	2119^{ab}	1598^{ab}	30.7^{ab}
Redgram stalk biochar 2.5 t ha^{-1}	31.3^{b}	96^{ab}	1891^{b}	1568^{ab}	28.5^{c}
Redgram stalk biochar 5 t ha^{-1}	**34.6^{a}**	**105^{ab}**	**2202^{a}**	**1661^{a}**	**31.1^{a}**
Prosopis biochar 2.5 t ha^{-1}	28.8^{b}	90^{b}	1812^{b}	1498^{b}	26.7^{d}
Prosopis biochar 5 t ha^{-1}	30.7^{b}	104^{ab}	2008^{ab}	1588^{ab}	28.7^{c}
S.Em+	1.0	4.0	80.0	47.0	0.4
C.D.(p < 0.05)	3.0	13.0	237.0	140.0	1.1

So, if you see some case studies we can see that this is an effect of different biochars and its application rates on growth and yield attributes of groundnuts so we can see when you are applying. So, there are different types of arbuscular mycorrhizae, composted coir pith, enriched farmyard manure.

But when we are applying the biochar we are getting high plant height and also higher root nodules, high dry matter and then pod yield, good pod yield and also higher 100 seed weight also. And also when we are applying red gram stock biochar at 5 ton per hectare we also can get high bio plant height and also higher root nodules, high dry matter, high pod yield and high 100 seed weight. So, that shows the effect of different biochar on the growth and yield attributes of groundnut.

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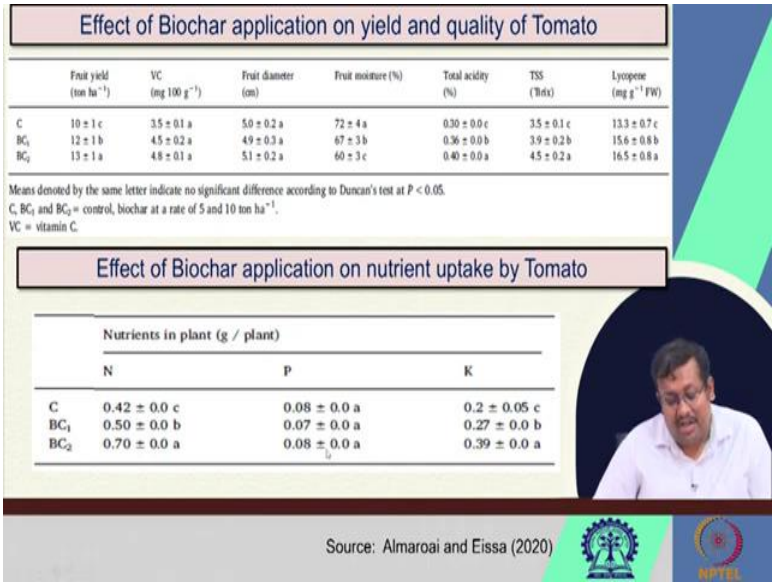

Also we can see effect of biochar application on yield and quality of tomato you can see when we are applying biochar 2 different types of biochar so bc1 and bc2 are basically biochar at the rate of 5 ton and 10 ton per hectare so when we are applying them we can see enhancing the fruit yield and also the other parameters.

So, here we can see the effect of biochar application nutrient uptake by tomato we can see when we are applying different types of biochar, biochar 1 and biochar 2, we can see uptake of nutrients implant we can see up is quite enhancing from this c is basically control as compared to control you can see the nitrogen uptaken in the plant is increase and also when we are applying more amount of biochar the more amount of nitrogen is being uptaken by the plant.

And similarly for potash also you can see there has been a significant increase in potash take when we apply the biochar. However, we have not seen any significant increase in phosphate uptake by the application of biochar in tomato.

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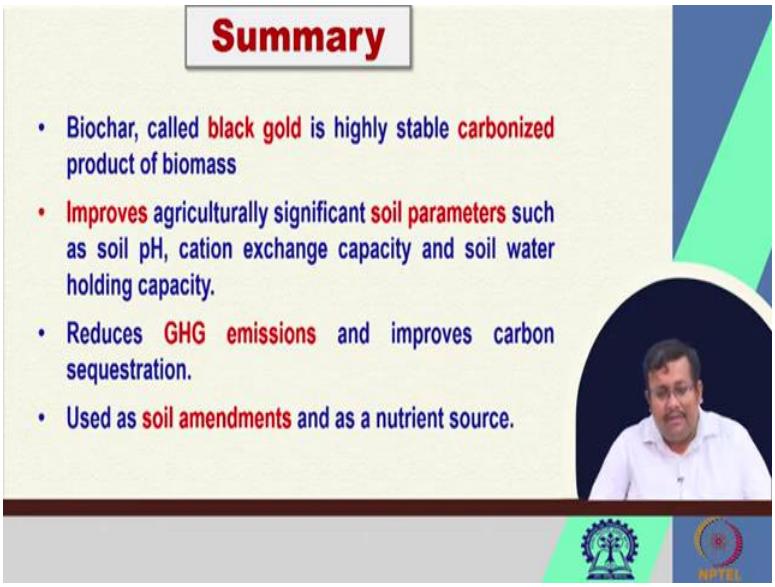

So, summarily guys we have seen that biochar called black gold in agriculture is highly stable carbonized product of biomass and we produce this biochar by different methods by anaerobically burning the crop residues through pyrolysis process and ultimately it will convert into this carbonaceous compound.

So, these biochar improve agriculturally. So, summarily what we have seen? So, summarily we can see that biochar which is also known as black gold of agriculture is a highly stabilized carbonized product of biomass and we generally produce this biochar by different methods by through the process of pyrolysis where this plant biomass is converted into biochar, it improves the agriculturally significant plant soil parameters, such as soil pH, catenation capacity and soil water holding capacity.

And it reduce the greenhouse emission and sustain, sorry, so summarily we can see that biochar which is also known as black gold of agriculture is a highly stable carbonized product of biomass. It improves agriculturally significant soil parameters such as soil pH, catenation capacity and soil water holding capacity. It reduces the greenhouse gas emissions and improves carbon sequestration. And it is used as soil amendments and as a nutrient source.

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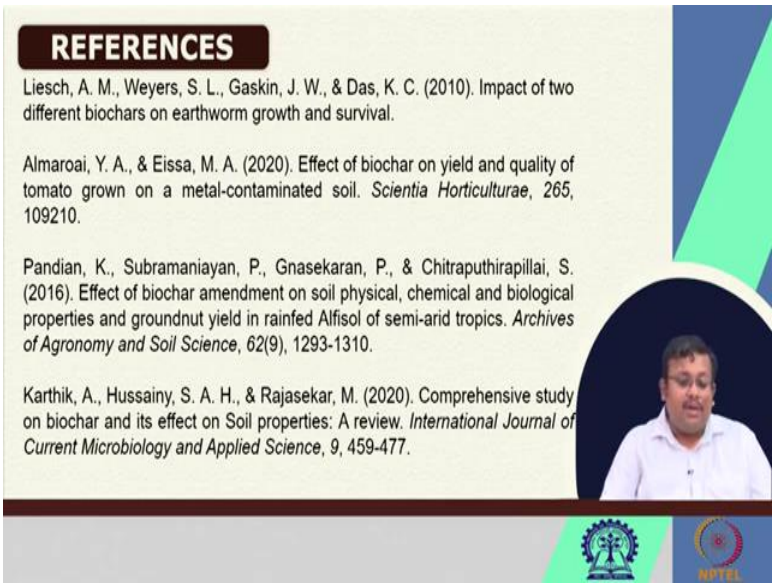

So, I hope guys you have got some basic idea about biochar. And there are different references for biochar, you can find different research papers focusing on biochar applications and they are on harnessing their benefits from soil. So, you guys can go ahead and see those papers and research articles to enrich yourself about biochar properties. Let us wrap up this lecture here and let us meet in our next lecture to discuss other management aspects of fertilizers and manures. Thank you.