

Soil Fertility and Fertilizers
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Lecture – 48

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

Welcome friends to this lecture of NPTEL online certification course of soil fertility and fertilizers. And we are going to start lecture number-48 in week 10. And in this week we are discussing about biofertilizers and management of fertilizers and manure. Now, in this lecture, we are going to focus on another important management technology that is called mulching. In our previous 2 lectures of this week, we have already discussed about biofertilizers, which are very important nowadays as far as the soil fertility is concerned.

Also, we have discussed about biochar, which is an important amendment for soil, or important input for the soil for augmenting the soil fertility. We have discussed those in details. In this lecture, we are going to focus on mulch and different types of mulching.

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The slide features a dark blue header with the text 'CONCEPTS COVERED' in white. Below the header, a list of five topics is presented in blue text, each preceded by a right-pointing arrowhead. The topics are: 'How mulch works?', 'Which materials can be used as mulches?', 'Effect of mulching on soil physical properties', 'Effect of mulching on soil chemical properties', and 'Effect of mulching on soil biological properties'. On the right side of the slide, there is a circular inset video frame showing a man with glasses and a white shirt. At the bottom of the slide, there are two logos: the Indian Institute of Technology (IIT) Kharagpur logo on the left and the NPTEL logo on the right.

So, these are the concepts which we are going to focus in this lecture. First of all, how mulch works, and then which materials can be used as mulches; and then effect of mulching on soil physical properties, then effect of mulching on soil chemical properties, and then effect of mulching on soil biological properties. So, these are the broad topics which we are going to cover in this lecture. Now, remember that mulching is a very important practice or management

concept, which we generally use for several beneficial purposes, like to conserve the moisture, to conserve the soil, to reduce the soil erosion.

So, there are several benefits of mulching; and there are several methods for doing the mulching, and we are going to discuss all of them.

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KEYWORDS

- Mulching
- Organic mulches
- Inorganic mulches
- Mixed mulching
- Flat mulching

The slide features a dark blue header with the word 'KEYWORDS' in white. Below the header, five bullet points list mulching methods. A circular video inset in the bottom right shows a man in a white shirt. At the bottom, there are logos for IIT Bombay and NPTEL.

Now, these are the concepts keywords which we are going to focus in this, or we are going to discuss in this lecture mulching, organic mulches, inorganic mulches, then mixed mulching, and flat mulching. So, these are the some of the keywords which we are going to discuss in this lecture.

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MULCHING
An Effective tool for modifying soil environment

EFFECT OF MULCHING ON SOIL PROPERTIES

Now, you can see in this picture; these are different types of mulch. We can use either crop based mulching that means crop residue based mulching, where we are using the straw here in this picture. And also you can see, we can also use the plastic mulch for the mulching purpose. Now, let us see how this mulching works. So, the question which we are going to answer in this lecture is the effect of mulching on soil properties. Then, we can understand how this mulch works.

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INTRODUCTION

WHAT IS MULCH?
A **mulch** is any material, other than soil, placed or left at the soil surface for soil and water management.

Mulches are the materials placed over the soil surface to maintain moisture and improve soil condition.

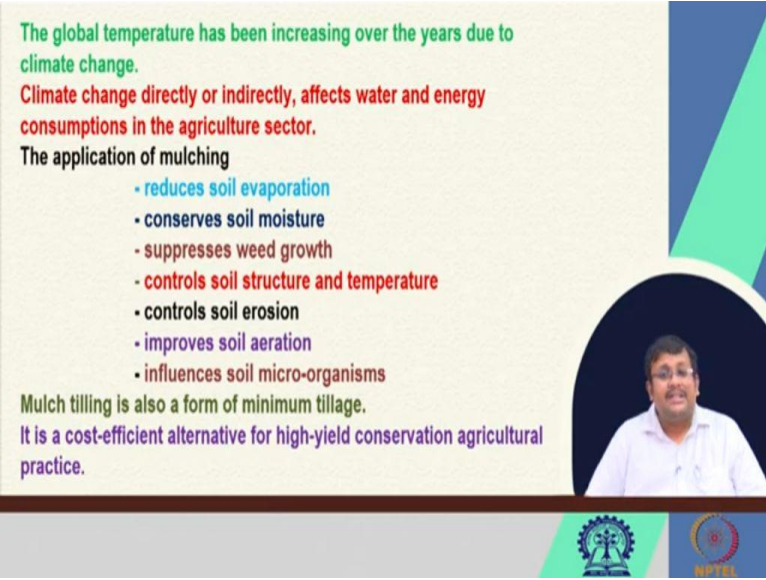
WHAT IS MULCHING?
In agriculture and gardening, **mulching** is the practice of leaving crop residues or other materials on the soil surface for soil and water conservation and keeping favorable and stable environments for plant growth.

The slide features a central graphic of five hexagons showing different mulching techniques: straw, wood chips, plastic, and organic matter. A video inset in the bottom right shows a male presenter in a white shirt. Logos for institutions are visible at the bottom.

Now, let us first define what is mulch? A mulch is any material, other than soil, placed on placed or left at the soil surface for soil and water management. So, in this picture you can see different types of mulching practices. So, mulches are the materials placed over the soil surface to maintain moisture and improve soil condition. So, a mulch can be any material, which we generally place or left at the soil surface to cover the soil for soil and water management. And basically, they are used for maintaining the soil moisture as well as to improve the soil condition.

Now, the next question comes what is mulching. So, in agricultural gardening or practices, mulching is the practice of leaving crop residues or other materials on the soil surface for soil and water conservation, and keeping favorable and stable environments for plant growth. Not only by covering the bare soil surface using different types of crop residues as well as plastic or any other material, we can ensure that we can conserve the soil and water. We can also ensure the favorable environments for the plant growth by mulching. So, these are some of the importance of mulching and mulching is a practice.

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The global temperature has been increasing over the years due to climate change.

Climate change directly or indirectly, affects water and energy consumptions in the agriculture sector.

The application of mulching

- reduces soil evaporation
- conserves soil moisture
- suppresses weed growth
- controls soil structure and temperature
- controls soil erosion
- improves soil aeration
- influences soil micro-organisms

Mulch tilling is also a form of minimum tillage.

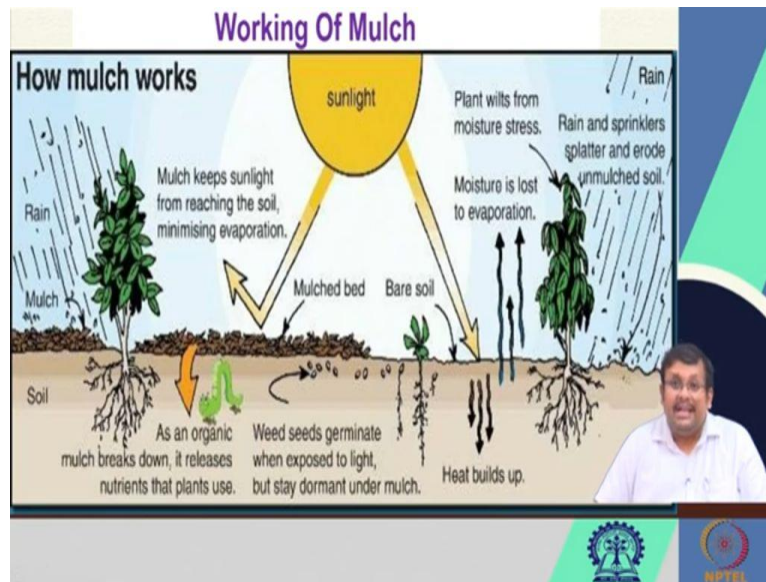
It is a cost-efficient alternative for high-yield conservation agricultural practice.

Now, so the global temperature we know that the global temperature has been increasing over the years due to climate change, which is a kind of a buzzword nowadays. Now, climate change directly or indirectly affects water and energy consumption in the agriculture sector. Now, the application of mulching basically reduces soil evaporation. Of course, when we are covering the soil surface using these crop residues or plastic sheet, we can reduce the soil evaporation; because if there is a bare surface that will encourage the evaporation of water from the soil, we can conserve.

In other words, we can conserve soil moisture, we can suppress the growth of the wheat weeds; and we can control the soil structure and temperature. How we can control the soil structure? Because, if we are using the mulching, then we can keep the soil out of the influence of abating action of the rain rainfall; and in that way we can conserve the soil structure. And also using the mulching not only we can conserve the soil moisture; we can also regulate the temperature or control the soil temperature for better crop growth. Now, of course, when we are covering the soil using mulching material that is controlling the soil erosion; and it improves the soil aeration, and it influences the soil micro-organisms also.

Now, mulch tilling is also a form of minimum tillage, where the minimum tillage is done; and basically the rest of the rest of the bare soil surface is covered using the mulching materials. Now, it is a cost efficient alternative for high yield conservation agricultural practices.

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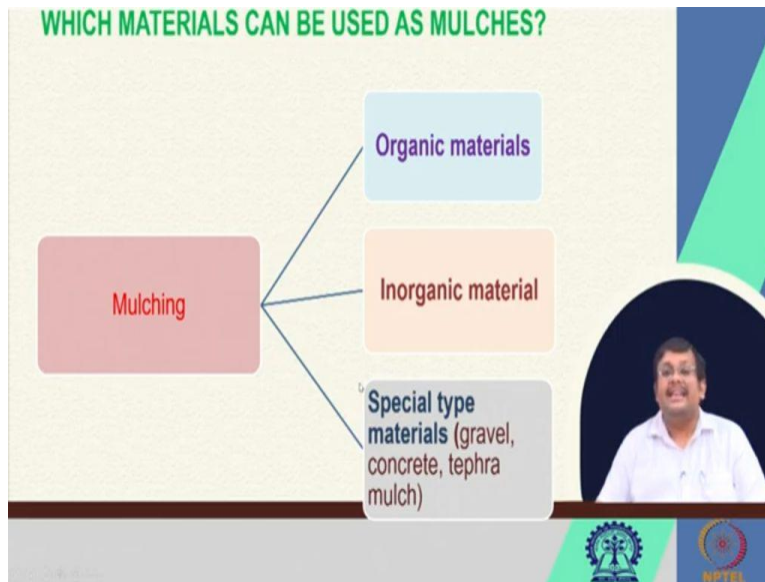


So, let us see in a pictorially how this mulch works. So, here you can see there are 2 conditions side by side. In right side, you can see there is soil surface bare soil surface without any mulch; and here you can see the soil surface with mulch bed. Now, when there is a direct sunlight, which is interacting with the soil surface, you can see that that can build up the weed heat; or that can build up the temperature. And as a result of that, the plants will wilt from moisture stress; and because moisture will be lost due to evaporation; and or whatever rains are sprinkler, splatters and erode on mulched soil.

So, basically when there is a rainfall, the rainfall will basically deep touch the soil surface, and will cause the soil erosion. So, these are the harmful effects of a bare soil surface. Now, on contrary we can see when we are putting this mulch, mulch bed, we are keeping the sunlight from reaching the soil; thus minimizing the evaporation, and also that can conserve soil moisture. And also weed seeds germinate when exposed to light, but stay dormant under the mulch. So, when there is a mulching that will make the seeds of the weed dormant and they will not germinate. And as an organic, as organic mulch breaks down, it releases nutrients that plant use.

So, since these are some of the some of these mulching materials are organic, they will break down; and it will release some of the nutrients that plants use. So, you can see that can also cover the soil from the baiting action of the rainfall; and as a result, there will be less, there will be less erosion from the soil.

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Now, so this is how mulching works. Now, next question comes to our mind what are different types of mulching materials. So, we can use either organic materials, or we can use inorganic materials, or we can use special type of metrics like gravel, concrete, tephra mulch et cetera as mulching materials.

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Organic Mulches

- It is the type of mulching in which the mulching material is always organic.
- Organic residues, grass clips, leaves, hay, straw, shredded bark, whole bark, husk, paper, animal waste, cover crop etc. are used.
- Organic mulches are temporary, and decay over time.
 - They add organic matter in soil
 - Increase water retention capacity
 - Provide nutrients

Now, of course organic materials are crop residues; and the inorganic materials are plastic sheet. So, let us talk about the organic mulches. You can see some of the good pictures of organic mulch. So, it is a type of mulching in which the mulching material is always organic, and organic

residues, then grass clips, then leaves, hay, straw; and then shredded bark, whole bark, husk, then paper, then animal waste, cover crop et cetera are generally used as mulching material. Organic mulches, remember, are temporary and decay over time. Since they are organic, they can decay over time; because at the same time, when they are decaying or decomposing, they are adding organic matter into the soil, and they increase the water retention capacity.

Because, the addition of organic matter in the soil can improve the water retention; because soil organic matter has high water holding capacity. And during the decomposition also, they can provide the nutrients, they can release the nutrients for the plant growth. So, these are the these are different types of organic mulches, and these are the benefits of using the organic mulches.

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Inorganic Mulches

- In this form Mulching material is always from inorganic sources(synthetic).
- The material used in this type is usually polymer film, plastic bags, nylon sheets, etc.
- They do not decompose with time.

Mixed mulching

The mixed applications of organic and inorganic materials as mulching treatments were also practiced under various crop conditions in different climatic zones .

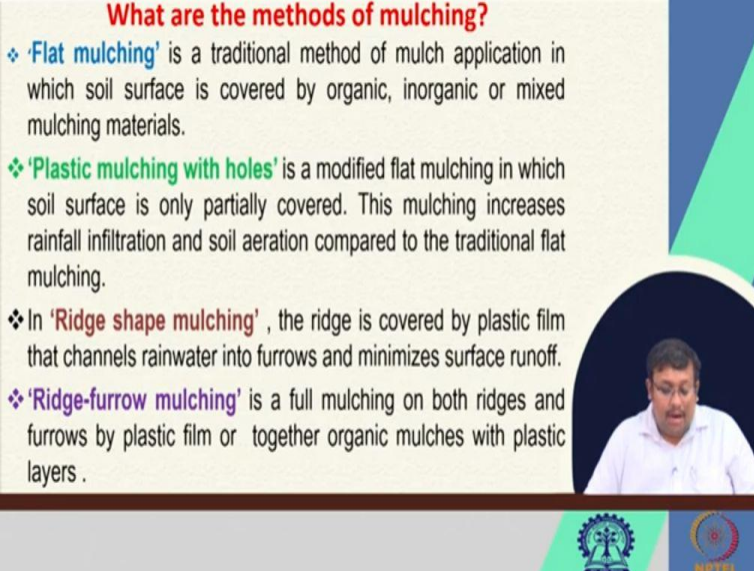
The slide features three photographs: two showing rows of crops in fields covered with black plastic mulch, and one showing a man in a white shirt speaking. At the bottom, there are logos for a university and a research organization.

Now, next is inorganic mulches. Now, in this form mulching material is always formed inorganic sources or synthetic materials. The materials used in this type is usually polymer film, plastic bags, and nylon sheet. As you can see in this picture, the the bare surface is basically covered by these plastic sheets or polymers polymer film. Now, what is mixed mulching? So, mixed mulching is the mixed application of organic and inorganic materials as mulching treatments. And these are also practiced under various crop condition in different climatic zones.

So, not only we are going for exclusive organic mulches or exclusive inorganic mulches, we can mix them together as a mixed mulching; and we can also use them for conserving the soil

moisture as well as the soil, also the soil materials from the action of sunlight as well as from the rainfall.

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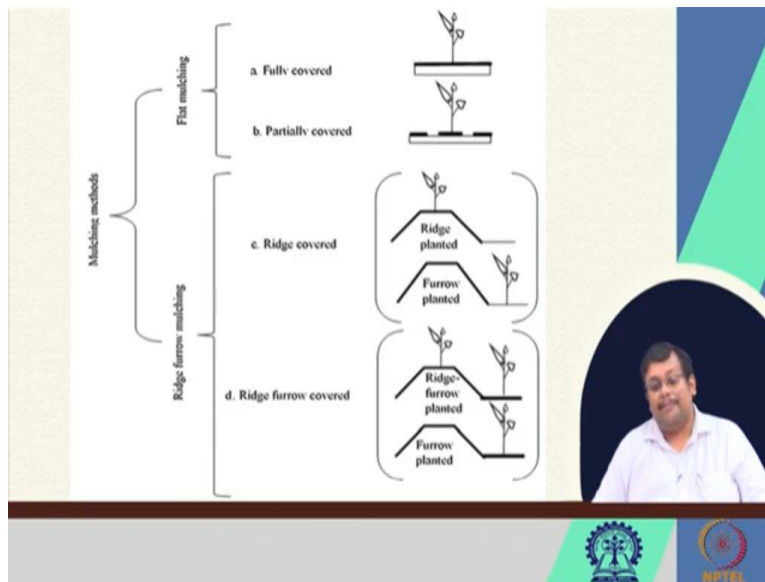
What are the methods of mulching?

- ❖ **'Flat mulching'** is a traditional method of mulch application in which soil surface is covered by organic, inorganic or mixed mulching materials.
- ❖ **'Plastic mulching with holes'** is a modified flat mulching in which soil surface is only partially covered. This mulching increases rainfall infiltration and soil aeration compared to the traditional flat mulching.
- ❖ In **'Ridge shape mulching'**, the ridge is covered by plastic film that channels rainwater into furrows and minimizes surface runoff.
- ❖ **'Ridge-furrow mulching'** is a full mulching on both ridges and furrows by plastic film or together organic mulches with plastic layers.

Now, what are the methods of mulching? The one of the method is called flat mulching. So, flat mulching is the traditional method of mulch application, in which soil surface is covered by organic, inorganic or mixed mulching materials; this called flat mulching. Second one is plastic mulching with holes. So, it is a modified flat mulching in which soil surface is only partially covered. Now, this mulching increases the rainfall and soil aeration compared to the traditional flat mulching. So when there is a plastic mulching with hole this can increase the water infiltration and also soil aeration, because some areas are still bear or uncovered.

Third one is ridge shape mulching. So, in this mulching the ridge is covered by plastic film that channels rainwater into furrows and minimizes surface runoff. And ridge-furrow mulching, which is a full mulching on both ridges, and furrows by plastic film or together organic mulches with plastic layers. I will show you the difference between ridge mulching and ridge-furrow mulching and so, and the other mulching types.

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Now, if we see here, these are different mulching methods; so we can see this is a flat mulching. So, in the flat mulching you can see the fully covered flat mulching; and also you can see partially covered flat mulching. In case of ridge-furrow mulching, we can see ridge covered mulching as well as ridge-furrow covered mulching, both of them. Now, these are 2 types of ridge covered, like ridge planted; so we are planting in the ridge and we are covering that. And in the furrow mulching furrow planted, we are planting in the furrow; and we are covering the ridge.

So, in these 2 cases, one is in both the cases, we are covering the ridge; however, in one case we are planting in the ridge; in another case, we are planting in the bare furrow. Another method is called ridge-furrow covered, where we can grow crops in both region furrow, and both of them are covered. And also where both of them are covered like the the crops are planted in the furrow; and both ridge and furrow are planted. So, these are different types of mulching methods under the broad category of ridge-furrow mulching.

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A. BULK DENSITY AND SOIL POROSITY:
Soil porosity at three different depths in soil treated with bare soil(CK), cobblestone (CB), water permeable bricks(WPB), pine barks(PB), green waste compost (GWC), & turf grass(TG).

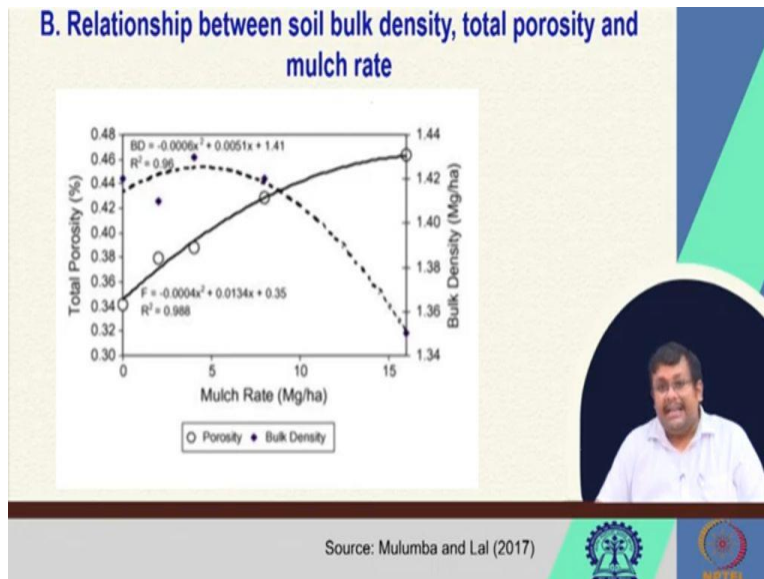
Depth	Treatment	Total Porosity(%)	Macro porosity(%)	Micro porosity(%)
0-10cm	CK	44.28	36.47	7.81
	CB	45.13	35.97	9.16
	WPB	40.64	33.46	7.18
	PB	47.21	37.84	9.37
	GWC	49.96	39.67	10.29
	TG	48.31	40.96	7.35
10-20cm	CK	43.64	35.41	8.23
	CB	43.71	36.77	6.94
	WPB	41.27	35.09	6.18
	PB	44.54	37.69	6.85
	GWC	48.72	40.06	8.66
	TG	46.80	37.86	8.94
20-40cm	CK	41.92	35.02	6.90
	CB	42.98	35.84	7.14
	WPB	41.76	35.25	6.51
	PB	42.76	35.24	7.52
	GWC	41.69	35.18	6.51
	TG	43.40	35.98	7.42

Source: Duiker and Lal (1999).

Now, let us see the effect of mulching at different depths on soil porosity. We can see here there are CK stands for, these this is basically a case study, where the CK stands for the bare soil; and then CB stands for the cobblestone based mulching; and then WPB stands for the water permeable bricks, and then PB stands for the pine barks mulching, and green waste compost is GWC, and turf grass is TG. So, in these different types of coverage, we can see at different depths. How this total porosity is increasing and bulk density is changing with different types of cover?

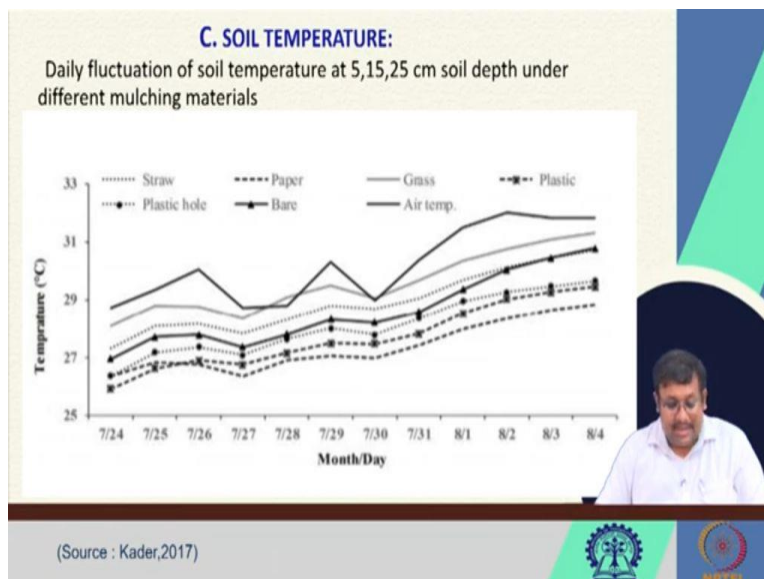
So, we can see at 0 to 10 centimeter, we are getting the highest highest porosity in case of the green waste compost. And also we are getting the highest macro porosity with the turf grass; and also we are getting the micro porosity highest micro porosity with the green waste compost. So, we can see at different depths, how these properties are changing based on different types of coverage.

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Now, also we can see in this case study the relationship between soil bulk density, total porosity and mulch rate. So, we can see as we increase the mulching rate in mega gram per hectare, we can see total porosity is also increasing; at the same time bulk density is decreasing. So, of course, when there is an increase in total porosity, we are getting lower bulk density; so, both of them are beneficial for the crop growth. So, mulching actually improves the soil physical condition by increasing the total porosity and also by decreasing the bulk density.

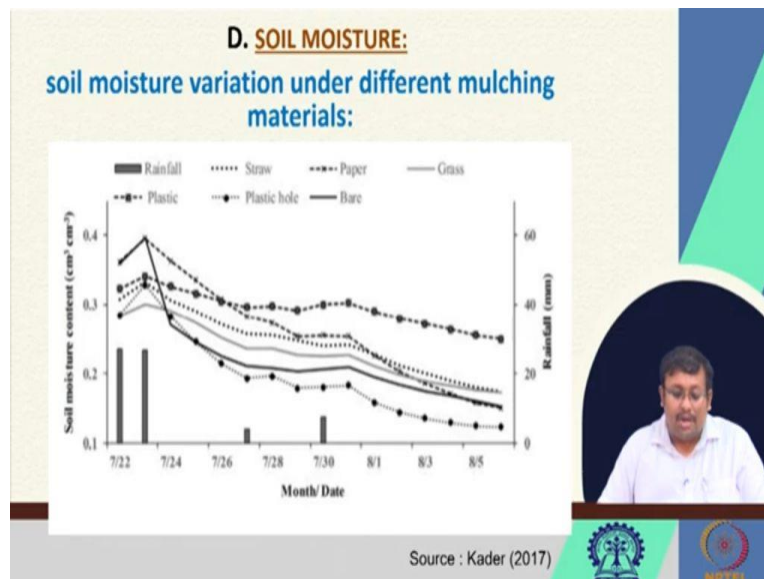
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If we want to see the impact of mulching on soil temperature, you can see the daily fluctuation of soil temperature at 515 and 25 centimeter of soil depth under different mulching materials. So, this is air temperature, so you can see these is the variation of temperature soil temperature, as the changes of the soil as the changes of month and day. And you can see here monthly changes of soil temperature, this black solid line; and you can see these are different types of mulches. So, one thing is for sure that when we are using the mulching material that is basically reducing the soil temperature which will be beneficial for the growth of the plant.

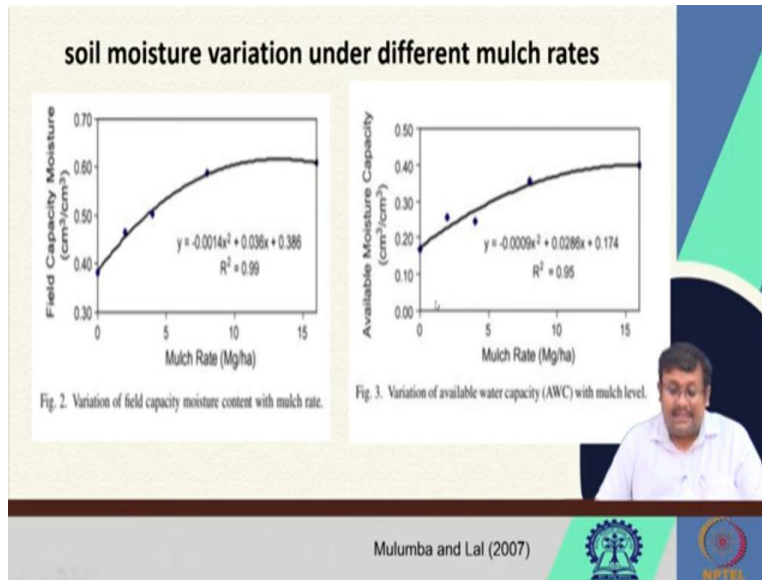
So, we can see here the temporal variation of soil temperature and to control the soil temperature, we can use different types of mulching materials.

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Now, if we want to see the soil moisture variation under different mulching materials, we can see here when there is rainfall. So, in the x-axis basically these are temporal scale, and in the y-axis we can see soil moisture content. We can see that as compared to the bare soil when we are using the mulching materials, they are conserving more moisture. So, the soil moisture content is increasing with the use of different mulching materials. So, these are some of the positive impact of mulching for conserving or for soil moisture.

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Now, also we can see the soil moisture variation under different mulch rates. So, as the mulching rates increases, we can see field capacity moisture is also increasing. And also we can also see with the increasing mulching rate, we can see increase in available moisture capacity. So, these are some of the beneficial effects of soil moisture beneficial effects on field capacity as well available moisture capacity with the mulching rate with the increasing mulching rate.

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Crusting and Sealing:

- Plant residues on the soil surface protect it against crusting and sealing
- Increasing SOM content decrease soil surface sealing.
- gravel mulch helps to avoid soil sealing and crusting
- Sometime plastic mulch increases the risk of crust formation.

Soil aeration:

- Crop residue mulch improves soil aeration by promoting free exchange of gases between the soil and the atmosphere.
- Oxygen diffusion rate is higher under mulch than under unmulched condition.
- Very high levels of CO₂ build up takes place under the plastic, as the film does not allow it to escape.

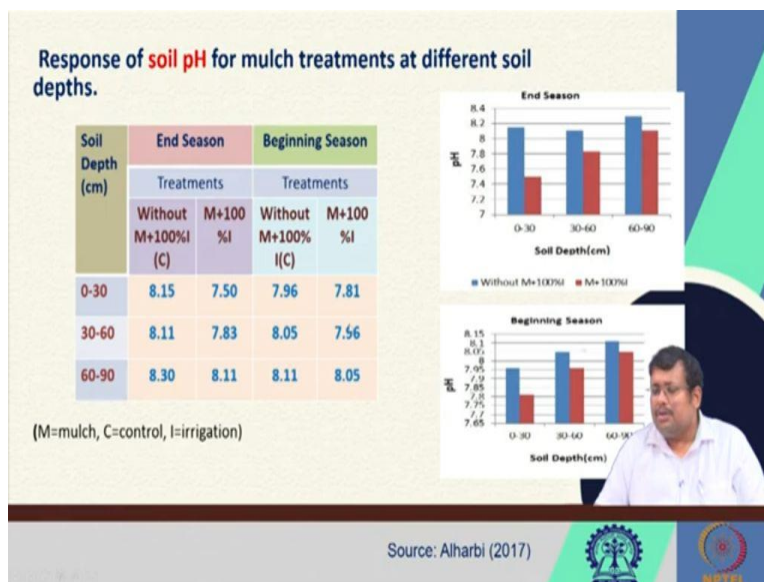
Now, what are the impact on crusting and sealing? How does mulching can impact the crusting and sealing? Now, plant residues on the soil surface can protect the soil against crusting and

sealing; we know what is soil crusting and soil sealing. Because when there is an increase of soil organic matter that can decrease the soil surface sealing, and gravel mulch helps to avoid soil sealing and crusting. And sometimes plastic mulch increases the risk of crust formation also. Because, when there is a cover over the soil surface that will basically protect the soil from the impact of the rainfall; and as a result there will be less detachment of soil particles.

As there will be less detachment of the soil particles, there will be less clogging, less sealing and less crust formation. Soil aeration is another important issue which we can address by using mulching. Now, crop residue mulch improved soil erosion by promoting free exchange of gases between the soil and atmosphere. And secondly oxygen diffusion rate is higher under mulch than under unmulched condition. And very high levels of carbon dioxide build up takes place under the plastic, as the film does not allow you to escape. So, when there is a plastic mulch, there is a chance of high levels of carbon dioxide buildup; because that cannot escape it, that cannot escape the mulching cover.

And also oxygen diffusion rate is higher under mulch than under unmulched condition. So, these are some of the impacts on crusting and sealing, and soil aeration by mulching materials.

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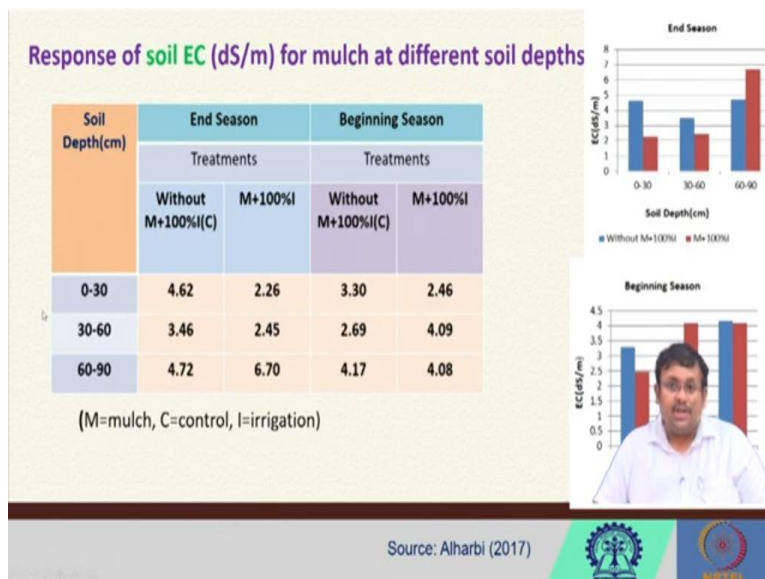


Now, if we want to see the response of soil pH for mulch treatment at different soil depths, we can see at different soil depths 0 to 30 centimeter, 30 to 60 centimeter, and 60 to 90 centimeter; without mulch plus 100 percent of irrigation, and mulch plus 100 percent of irrigation, end

season and beginning season. We can see that the soil pH basically are less impacted. So, without mulch you can see as we go down, the soil pH is quite high. However, when we are using the mulch, we are stabilizing the soil pH towards the, towards the neutral range; and that is helpful for up taking the nutrients.

Similarly, we can see here in this beginning season treatments also, as we are going down that is increasing the soil pH. However, by using the mulch at least for 0 to 30 and 30 to 60 centimeter, we are able to we are able to control the soil pH. So, these are also the benefits of using mulching for conserving, or to or acts as a buffering for soil pH.

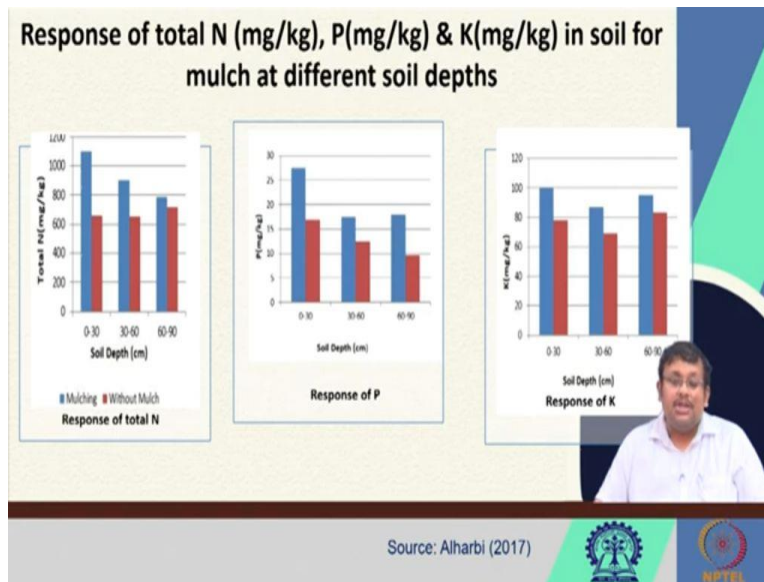
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Also if we want to see the response of soil electrical conductivity by using different mulching material, you can see here without mulch plus 100 percent irrigation you can see. In the control plot, you can see that those plots are having higher salinity. However, when you are using the mulching at least up to 60 centimeter, we can see they are showing reduced salinity stress. At the same time we can see here, in the beginning season also similar trend can be observed at least in the 0 to 30 centimeter depth.

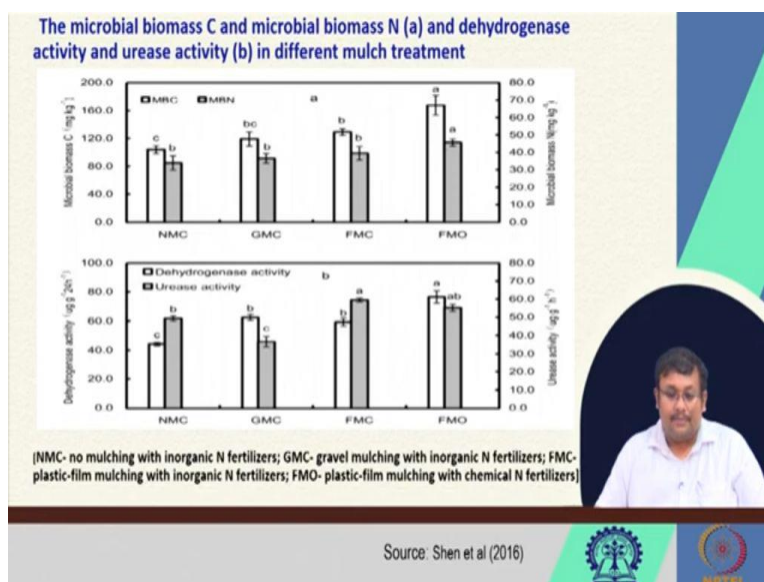
So, these are some of the important benefits of using the mulching material for controlling not only the soil erosion, but also for controlling the soil electrical conductivity as well as soil pH.

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Now, if you also want to see the response of total nitrogen, phosphorus and potassium in soil for mulch at different soil depths, you can see when you are using mulching, the total nitrogen, total phosphorus and total potassium response are also increasing. So, not only a different improvement of different physical condition, but also for improving different types of chemical condition also, this mulching is very much important. And this mulching thus is recommended by the scientist for better crop growth. Because, it can not only produce the favorable soil physical condition but also favorable soil chemical condition also.

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Now, if you want to see the microbial biomass carbon, and microbial biomass nitrogen, and dehydrogenase activity, and urease activity in different mulching treatment; we can see this is NMC stands for no mulching with inorganic nitrogen N fertilize. GMC stands for gravel mulching with inorganic nitrogen fertilizer. FMC stands for plastic film mulching with the inorganic nitrogen fertilizer; and FMO stands for the plastic-film mulching with chemical nitrogen fertilizer. So, we can see here with FMO, we can see higher microbial biomass carbon; and similarly, we can also see the higher dehydrogenase activity with FMO.

So, that shows as compared to the NMC. So, that shows not only the physical properties not only the chemical properties, but also the biological properties can also be improved by using the mulching practices.

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Does Mulching has any negative impact?

Although, mulching has many advantages, it has some negative effects also.

- The major negative consequence of the use of plastic mulch is related to **handling the plastic wastes**.
- The plastic film residue **reduces soil porosity** and hence air circulation, changes microbial communities and leads to low soil fertility.
- The **plastic film mulching** significantly **reduces soil organic matter** and greatly increases greenhouse gas emissions.
- They promote soil degradation, cause soil-water repellency and occur as **potential pollutants** in the soil.

The slide includes a video inset of a man in a white shirt speaking. At the bottom, there are logos for a university and a research center.

So, the next question comes to our mind; so, mulching has all these positive effects. Does mulching has any negative impact? Yes, although mulching has many advantages, it has some negative effects also. So, the major negative consequence of the use of plastic mulch is related to handling the plastic with wastes. So, the plastic because plastic is you know non-degradable, biodegradable, so that can create environmental problems. So, the plastic film reduce residue reduces soil porosity; and hence air circulation changes and also reduces the air circulation.

It changes the microbial communities and leads to low soil fertility sometimes. The plastic film mulching significantly reduces soil organic matter, and greatly increases greenhouse gas

emission. As I have already told, there will be a buildup of carbon dioxide; and they can promote the soil degradation. And can cause soil water repellency and occur as potential pollutants in the soil. So, these are some of the negative impact of plastic mulching.

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Does Mulching has any negative impact?

- Organic mulching materials such as wood chips and bark may occur as **soil acidifiers**.
- **Too much organic mulch** can lead to excess moisture, creating new problems such as pests, anaerobic conditions and rotting of the roots that can damage the plants.
- When carbon rich materials such as straw or stalks are used for mulching, **nitrogen from the soil may be** used by microorganisms for decomposing those materials.
- Thus, nitrogen may be **temporarily not available** for plant growth.

The slide features a video inset of a man in a white shirt in the bottom right corner. At the bottom, there are logos for IITM (Indian Institute of Technology Madras) and NITM (National Institute of Technology Manipal).

Organic mulching materials such as wood chips and bark may occur as also soil acidifiers. So, when we apply them that can also enhance soil acidity which is not favorable for plant growth. Too much organic mulch can also leads to excess moisture, and excess moisture creating new problems such as pests, anaerobic condition, and rotting of the roots that can damage the plants. And when carbon rich materials as straw or stalks are used for mulching, nitrogen from the soil may be used by microorganisms for decomposing those materials. And as a result, the nitrogen may be may be temporarily unavailable for plant growth. So, these are some of the negative impact of plastic mulching and organic mulching.

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- Mulch farming is a **form of conservation tillage** that preserves soil quality and the environment.
- Mulch affects soil physical properties by **improving SOM content** and increasing soil porosity.
- The mulching materials, by **modifying the microclimate and reducing soil evaporation**, exert significant impact on the **water-saving in agriculture**.
- However, every type of mulch has **some strengths and weaknesses**, making it suitable for some situations and not for others.

Now, mulch farming is a form of conservation tillage that preserves soil quality and the environment. So, summarily we can found we can understand that this mulching is important; it has some negative impact. But, at the same time, it is a form of conservation tillage that preserves soil quality and the environment; and mulch affects soil physical properties by improving soil organic matter content and increasing soil porosity. The mulching materials, by modifying the microclimate and reducing soil evaporation, exert significant impact on the water saving in agriculture.

However, every type of mulch has some strength and weaknesses, making it suitable for some situation and not for others. So, these are some of the important aspects of mulching.

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A presentation slide with a light beige background and a dark blue and green geometric design on the right. It features three bullet points in red and blue text. A circular inset on the right shows a man in a white shirt. At the bottom, there are logos for a university and NPTEL.

- Availability, durability and cost of the materials are the important issues to be taken into considerations for the selection of mulching materials.
- The main focus should be to reduce the negative impacts of mulching.
- To get maximum benefit from mulching, it is imperative to investigate the effects of different mulching materials under various field conditions for the best fit of the materials to the crop and climate.

Availability, durability and cost of mulching materials are the important issues to be taken into consideration for the selection of mulching materials. And the main focus should be to reduce the negative impact of mulching which we have just discussed. And to get the maximum benefit from mulching, it is imperative to investigate the effects of different mulching materials under various field conditions for the best fit of the materials to the crop and climate.

(Refer Slide Time: 29:24)

A presentation slide titled 'REFERENCES' in a dark blue box. It lists five scientific references in black text. A circular inset on the right shows the same man in a white shirt. At the bottom, there are logos for a university and NPTEL.

REFERENCES

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Alharbi A., 2017. Effect Of Mulching on soil properties under organic farming conditions in center of Saudi Arabia. Scientific procedures V international scientific technical conference "AGRICULTURAL MACHINERY" 2017, Year I, Vol 2, P.P 230-236

Mulumba L.N., Lal R., 2008, Mulching effects on selected soil physical properties, Soil Tillage Res. 98, 106-111.

Kader M.A., Senge M., Mojd M.A., Ito K., 2017, Recent advances in mulching materials and methods for modifying soil environment, Soil Tillage Res. 168, 155-166

Duiker, S.W., Lal, R., 1999. Crop residue and tillage effects on carbon sequestration in a Luvisol in central Ohio. Soil Till. Res. 52, 73-81

So, guys, by this week, by this let us wrap up this mulching discussion. And these are the references which you can see for gathering more information regarding mulching. And

so, let us wrap up this lecture here; and let us meet in our next lecture to discuss some other important concepts. Thank you very much.