Nanotechnology in Agriculture
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Lecture-21
Mechanistic Details of the Action of Pyrite Nanoparticle

So welcome back to the lecture series in nanotechnology in agriculture, so we were discussing about iron pyrite as the seed by stimulant. So next couple of classes we will be discussing about the mechanism of action by virtual iron pyrite helps in enhancing the production of the crops. So as of now it has been clear to most of you that iron pyrite has a complete molecule is not entering most likely inside the seed. What is happening is that its sensitive in soluble in water, it is forming trace amount of hydrogen peroxide iron in+2 and +3 state.

And SO4–ironic species, so there are cations and the anions and a peroxide kind of a milieu and all these rest of these amounts all these cationic and anionic species+the peroxide is in a trace amount. And whatever is happening it is happening because of these ironic milieu. But then in my previous class I introduce the concept of why a seed is not allowed to germinate, I told you that germination is being prevented by a series of antioxidant molecules which are presented.

And as you know in the biological system there are 3 key antioxidant molecule catalyze peroxidase and so, peroxide dismutase. The nature has equipped as to live in an oxygen environment by virtue of these antioxidants. And here just I will take a (()) (02:25) tell you oxidant molecule can come very handy in your immune system where you have to destroy the foreign particles or foreign cells the most of the microphagous present in our body. They eject out your free radicals in order to destroy x, y, z.

But the same time these free radical can affect your system also by destroy cells. So, it is a kind of double digit cells**.** So, somewhere in between we have drawn this line of having a series of antioxidant enzymes which ensures there is a balance for oxidant and antioxidant kind of is being maintained okay. So resuming, so there are 2 concepts what we introduce and now today we are going to put all of them together okay.

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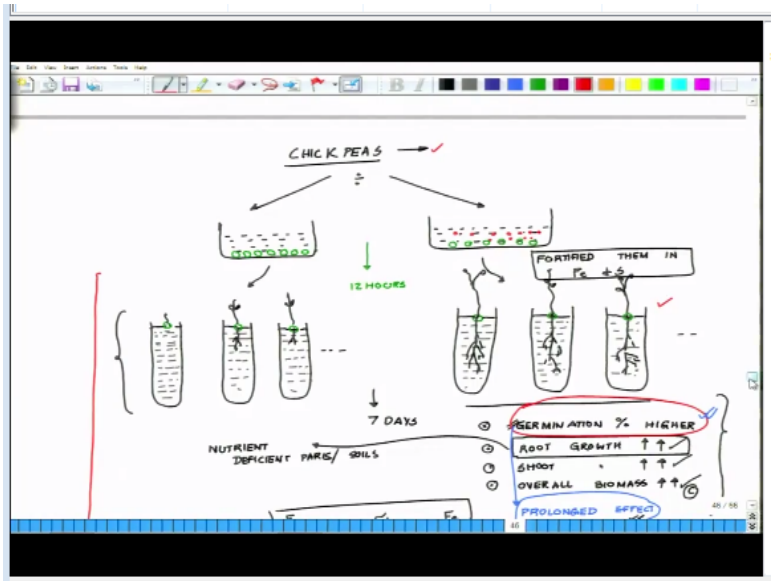

So, just as small recap I talk to you about the chickpeas where you saw how in the water post treatment the growth of the chickpeas post FeS2 treatment much more higher.

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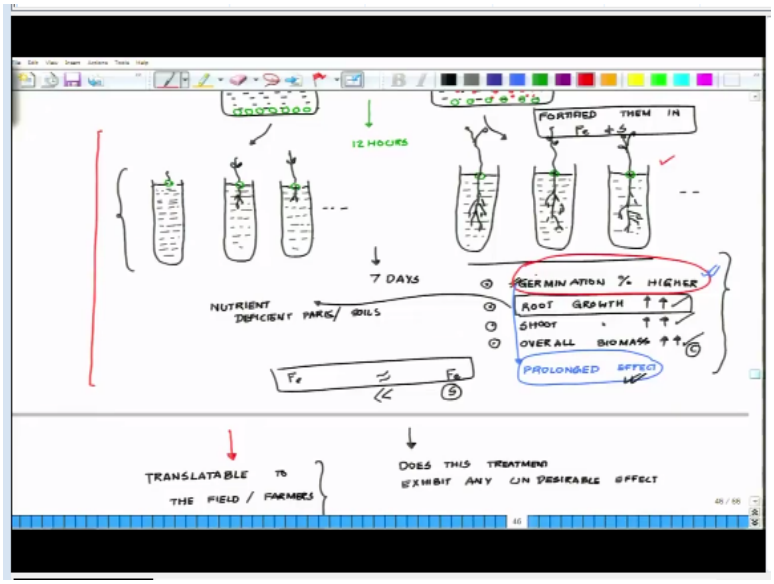

We talked about the increase germination percentage enhance to growth enhance should growth and over all biomass increase.

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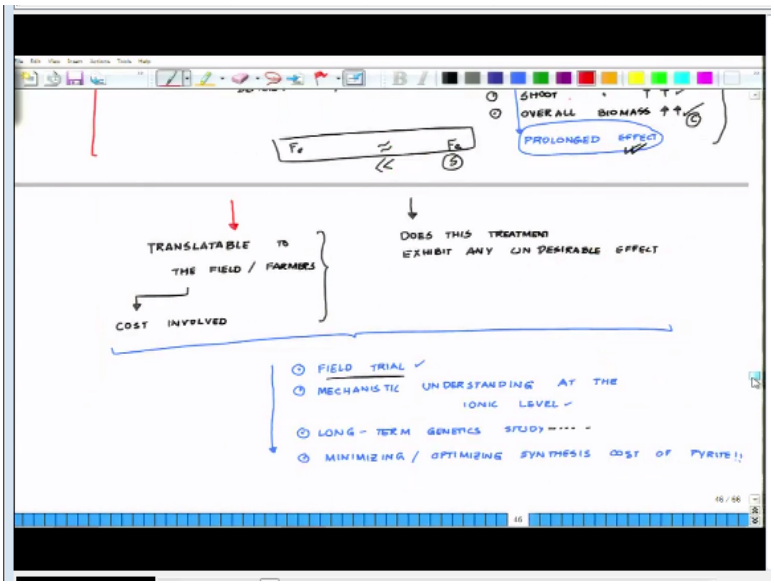

Then we talked about the field trials and in the field trial.

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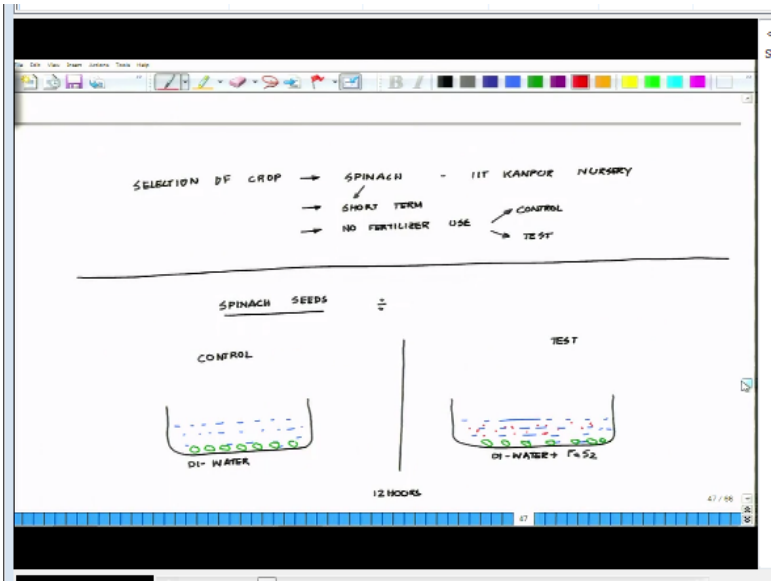

I talk to you about the spinach seeds and again for 12 hours treatment in water.

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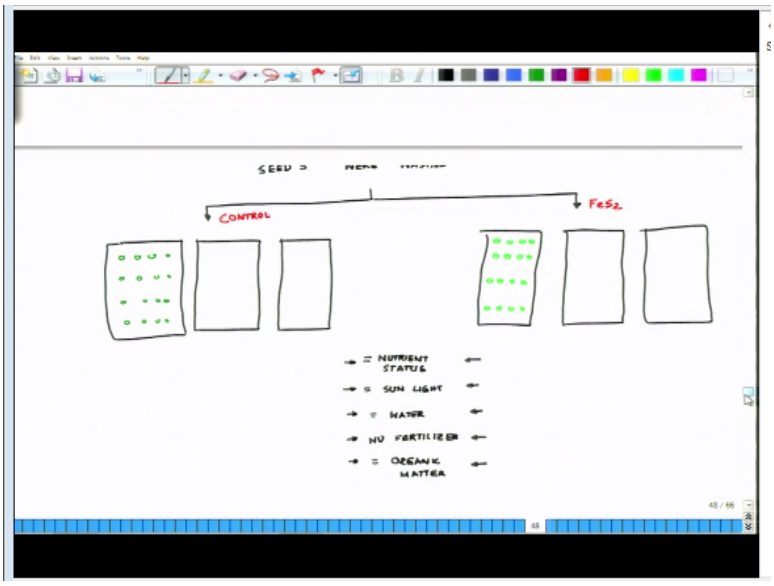

And correspondingly in water+iron pyrite pours that these plants were these seeds were shown maintaining same nutrient status for the soil same amount of sun light same amount of water no fertilizer.

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And equal amount of organic matter what is present in the soil.

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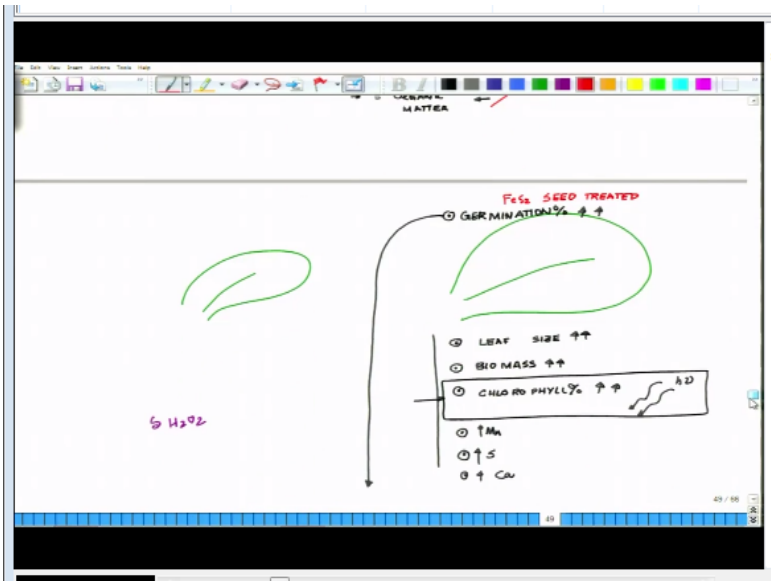

And what was observe there is an increase in the leaf size, there is a increase in the biomass, there is increase in chlorophyll, increase in manganese, sulphur, calcium.

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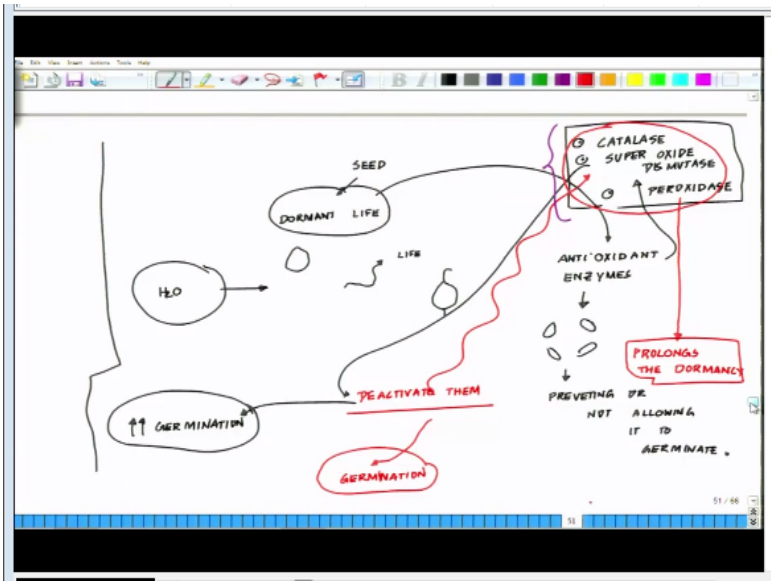

Now where from these effects are coming, so this is where we stopped told you that a dormant seed remains dormant. Because there is a battery of antioxidant enzymes which prevents are prolongs its dormancy. So to use the right trace here it prolongs the dormancy, now how it prolongs the dormancy and where pyrite acts onto it how it prolongs the dormancy before we get into that part that have prolong the dormancy let us again summarize.

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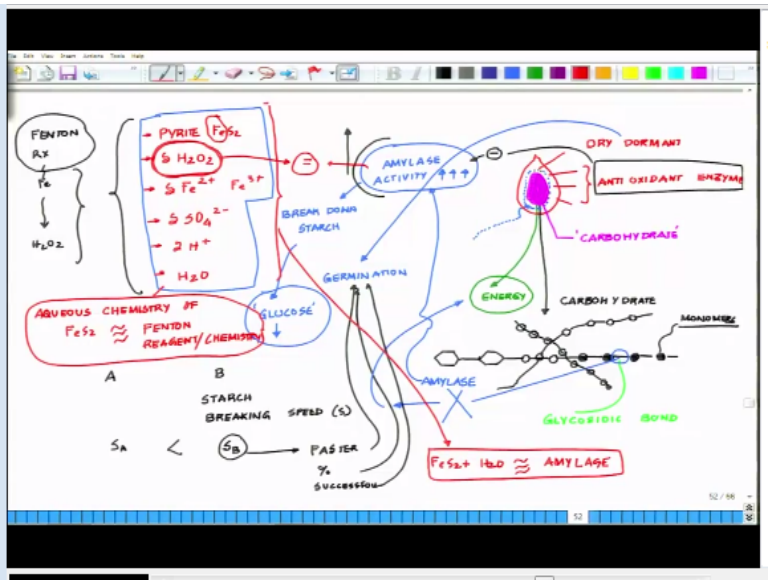

So, you are having pyrite, you are having trace amount of H2O2, trace amount of +, you are having SO4 to – and you are having trace amounts of H+ions and of course you are having water. And I told you a seed when you look at the seed, a seed in its dry dormant state has a battery of antioxidant enzyme. And seed has huge amount of a strong result of carbohydrate and this is this carbohydrate which decides or is the first source of energy.

Now this carbohydrate when seed is germinated is the water molecules which comes and it activates its enzymatic machinery around. And this carbohydrate is breaking down to generate energy, now what is breaking down the carbohydrate, the enzyme which is so those of you for about carbohydrates are long chain of glucose, galactose, manose and all sorts of thing. They could be starch extremely long chain that crisscross.

And there are lot of these features they collect, there are lot of these moieties forming like this ok. And the circle is presenting each one of those glucose and moieties and x1 so far, so these are crisscross chains like this long chains and this is what starch now this molecules are. So, now, so this is essentially a big carbohydrate molecule, now in order to break a carbohydrate molecule what one has to do is.

So the carbohydrate each one of these individual units what you see these are monomers, these monomers are attached or polymerized structure through a bond called glycosidic bond which is

this one. Now in order to break carbohydrate for it to release energy what one has to do is one has to break up this bond, if you can break up this bond then this we will release energy. And this is precisely the energy we are talking about.

But breaking this bond is not an easy job, there are specific enzymes which does that job and one of the key class of enzyme which does that job a amylase. So, amylase activity when the seed is from its dormancy is a heading towards germination what we absorbed is amylase activity goes up significantly. Because of the amylase activity going up significantly it leads to the breakdown of starch into small molecules like glucose.

This is your glucon-D almost, so basically you want to go for 100 meter dash take a glucon-D and you run this is precisely how a seed germinates in an environment which is extremely challenging for it to grow that is not easy. Now these producing sugars which are getting produced they are the once which are source of energy. Now if you think with the way we can histone this process of make the germination to happen is somewhere other.

If we could ensure the amylase activity is initiate, now what is the role of these antioxidant enzymes, so the antioxidant enzymes the prevents the amylase activity, that is what we does by stopping the amylase to act apart, what you absorb is amylase activity which is responsible for breaking down of the break the starch molecules is being stopped by this antioxidant enzymes.

So this is how nature maintains the balance, but the very moment water comes and started activating this zone the amylase gets into the plane. But now this is all fine, so for so good, then what makes the presence of pyrite so very important, so if you look at it chlorophyll and of course the germination percentage, how pyrite is thing a role in germination now look if you look previously also the same thing germination presenting.

So how thus material is acting, now this is like have to give a situation I am breaking a starch you are breaking a starch. But if I break a starch faster than you then I will be more harvesting more energy faster than you okay. So say for example you have A and you have B, so starch so

our test is starch breaking speed okay. So if the starch breaking the speed of S if I represented by S.

And SB is the starch breaking speed of B, if SB is more than SA than SB will germinate faster and more successfully okay faster germination and more percentage germination and more successful germination okay. Now is FeS2 playing such a role, now having said this I will come back and visit this molecule and if you look at this if you remember one old reaction called Fenton reaction where in the presence of iron it produce hydrogen peroxide very old chemistry.

I will request you to look at Fenton reaction, now if you look at the Fenton reaction and if you look on this red alphabets here or red words here something very similar to Fenton reaction production of H2O2 in the presence of iron. So in other word FeS2 chemistry or aqueous chemistry of FeS2, so let me put it aqueous chemistry of FeS2 is similar to or reclose to Fenton reagent or Fenton chemistry.

And having said this let me highlight one point here for those who are interested in degradation of organic waste which are carcinogenic which are extremely environmentally hazardous. They are places in the world where they use large amount of pyrites to execute those breaking of those huge organic molecule, how they do so now, here how they do so. You have these hydrogen peroxide here, peroxide can this is way back in 1920s is wonderful paper in general of biological chemistry which was published and said hydrogen peroxide can mimic mark my word carefully can mimic.

The activity of amylase, so in other word FeS2 are pyrite is mimicking whole thing is FeS2+water is similar to amylase okay.

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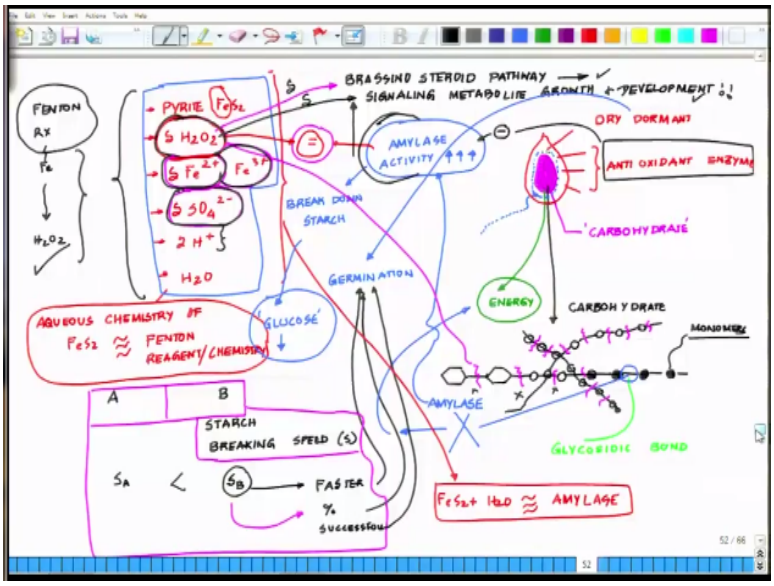

So, in other word one can consider FeS2+water system as equivalent to amylase or artificial starch breaking enzyme system okay. So, now let me get back the example what I gave you here just underlying this in pink. Now we have A and B and B has higher starch breaking speed, so automatically B will be performing faster and will be more successful that is precise the what is happening when FeS2 in the presence of water is generating this trace amounts of hydrogen peroxide which is mimicking amylase activity.

And going there and what it is doing is it is chopping of these glycosidic linkages and generating energy faster. So, it is generating more reducing sugar for more faster than naturally or in a normal process amylase is doing by the process. It is ensuring a faster germination and having faster germination leads to a faster growth and in that whole process the plant is getting as we will proceed further is getting a support from SO42 –Fe2 Fe2+Fe3+that will be discussing subsequent classes.

But there is one more thing happens this hydrogen peroxide apart from it possibly activates a pathway which is called brassinosteroid pathway which denotes a faster growth and lastly H2O2 itself is a signaling metabolize for growth and development. So, hydrogen peroxide by itself does multiducting that the problem in the challenges that you can argue that then why do not we put hydrogen peroxide directly the challenges.

It acts on such a trace amount that it is not really one of the translatable technologies second there are certain very unique role as we will diverged it further you will absorb of these released $SO4^{2-}$ Fe^{2+} Fe^{3+} and this milieu of slight acidic environment as we will proceed further well describe those how they play a role. So to conclude iron pyrite mimics in the presence of water a Fenton chemistry point one.

This is this point okay it while mimic Fenton chemistry generates hydrogen peroxide which mimics amylase activity. And just like amylase it breaks down or chop up the glycosidic linkage and thereby increasing the possibility of the plant to absorb more or get more energy in the shortest possible time. Because you have always have to realize when you put a seed in the soil it is facing one of the harshest environment you can think of it.

There are microbes there are completing seeds there are everything all of the place is opposing it. So, you know it has to grow faster it has to emerge out from the soil. So, in order to do that it has to really do it real quick real fast and that precisely this process is facilitating without even getting into it and then it possibly activates the brassinosteroid pathways in itself with the act of the signaling molecule for development

And as we will proceed further we were talked more of how FeS_2 affects the root geometry which has a profound impact on nutrient deficient soil.

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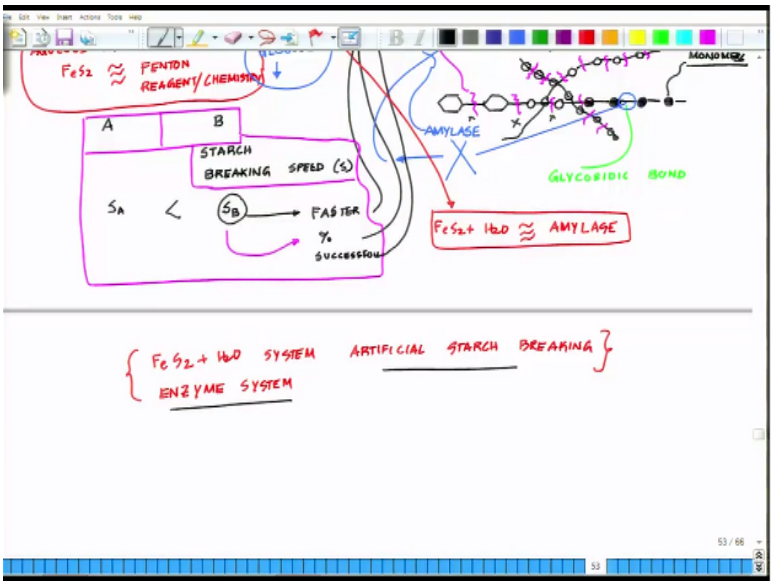

And further FeS2 water system is an artificial starch breaking enzyme system okay, so we continue this in our next class, thank you.