Micro Irrigation Engineering

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Lecture - 29
Fertigation Application Methods

Hello participants, I welcome you to lecture 29 of Micro Irrigation Engineering subject. This lecture is on fertigation application methods. We discussed in previous lecture 28, about the importance of fertigation, different types of fertilizers and in this lecture, we will discuss about different devices which are used to apply fertilizer using these devices.

So in this particular lecture, the methods of fertigation application, relative comparison of these methods of fertigation, and how to design the fertigation system will be dealt.

So when we are applying fertilizer or chemicals which are dissolved or soluble in water. This can be applied through using a Venturi injector or by using a pressurized fertilizer tank where there is an arrangement of bypass system or using an irrigation pump. So these devices are used.

Let us discuss in detail about all three types of devices, how do they function. So as the name says that it is a Venturi injector. So, Venturi, that it is a constricted passage. There is a constricted passage and in this passage, the water or fertilizer solution is being sucked. So the high flow velocity of water in the constriction, it reduces the pressure.

I will show you the diagram where you will see that why the pressure gets reduced and velocity increases. So this pressure it becomes sub-atmospheric pressure. So fertilizer solution is sucked from an open tank into the constriction through a small diameter tube. The process of injection of fertilizer can be explained by using the energy equation which is involving Bernoulli’s principle and assuming the inlet and outlet ports of the Venturi are kept at the same elevation.

So if you look at the Bernoulli equation, it is the pressure head plus velocity head plus elevation head is constant. Means, when we are taking if any particular head is reduced the other component increases. This is the basic principle because the right side of the equation is constant. So suppose the elevation head is zero, then pressure head and velocity head equal to constant.

Or we can say when the pressure head is less the velocity head will increase. So the different means your symbols here it is used. P refers to the pressure, V refers to the velocity, Z refers to the elevation and this is a gamma which is the unit weight of water, and G is the acceleration due to gravity.

So the rate of flow in the Venturi system can be regulated by using the valves. So here there are valves and these valves can be regulated, this could be regulated so as to allow the water flow. This is what you see here how the water is being supplied along with the fertilizer. So this is a fertilizer container and then using this Venturi it is attached here.

This is the Venturi, which is attached, this part is Venturi and this is attached and this fertilizer solution is sucked by using the Venturi, and then it is entering into the system. So this is a simple device and as such, it is an inexpensive method of fertilizer application.

And when you look at the diagram just for few minutes, you will see the concentration is increasing and then it goes to almost a constant means there it goes to a constant value of fertilizer and concentration after a certain time.

Now the concept of the Bernoulli principle is explained here that considering an inlet, so this is the inlet part and this is kept in the same elevation means this particular Venturi is kept in the same elevation. So initially the equation was pressure head plus velocity head plus elevation head was equal to a constant. Now we are taking two sections.

So one section is your inlet section of the Venturi and this is the throat section. So at this inlet section pressure head plus velocity head is equal to the pressure head plus velocity head. Now what is happening, the pressure head and say P is the pressure head at the inlet. P1 is the pressure head at the inlet end and V1 is the velocity head.

So at this point what happened because of the constriction, the area of the flow reduces, which causes an increase in the velocity of flow and there will be a condition when this pressure head at this point it will become sub-atmospheric. So fertilizer which is kept in this tank, it will start injecting into the system. So this means P1 or this pressure head between the two ends can be given by changing the velocity.

So change in the velocity is due to constriction in the Venturi pipe causes suction due to change in the pressure head from P1 to P2. That is below atmospheric pressure thereby the suction of fertilizer solution will take place.

Now we are demonstrating you here for testing a Venturi injector. This is a Venturi injector. Now, a Venturi injector is used to inject chemicals. This is used to inject chemicals. This chemical could be a nutrient which is soluble in water and that is being injected into the drip system. Now, a typical drip irrigation system, if you remember we discussed that the water is taken from the source.

So in the laboratory setup, we have got a sump where water is stored and then the water is being pumped by using an electric motor coupled pump which comes. This particular component is the suction end and that is the delivery end, so water which is coming at what pressure? So, a pressure gauge is mounted, we can know that how much is pressure available.

Then this part, if we are not injecting fertilizer then the water can directly go to the main pipeline. So here it goes to the filter and from the filter, it will go to the system. There is a water meter attached to this one. So how much amount of water is passing. Now, if we want to inject fertilizer, so a Venturi injector is connected. Now, Venturi injector, this is your demonstration setup.

We can test that how much amount of fertilizer or chemical or nutrient can be injected at a given pressure. So this is one pressure gauge, this is another pressure gauge and with the help of these two valves pressure is regulated.

This particular place where there is a reduction in the diameter of the pipeline causes the increase in the velocity of flow that will decrease the pressure, and thereby a suction will be created and due to a decrease in the pressure or increasing the suction, the Venturi will function and then it will start injecting fertilizers.

Now, you can see we are regulating the pressure and when we are regulating the pressure we are opening the knob. So, fertilizer has started injecting into the system. So at a given time the volume of water, because this is a graduated cylinder, one can know that in a given time, how much volume of fertilizer has been injected into the system. So for a given pressure, this is a pressure reading, and then what is the rate of injection that can be calculated.

This is a simple device. There is no moving part, easy to install and maintain, suitable for a very low injection rate. The injection can be controlled with a metering valve and this is suitable for both proportional and quantitative fertilization. Means proportional I mean to say that water and fertilizer resource, proportionality it can be maintained as well as the desired amount of the fertilizer it can be given with this method.

The disadvantage of this system, there is a considerable head loss due to constriction and attachment which causes. Sometimes it requires a booster pump to create an adequate head to supply fertilizer along with irrigation water. Quantitative fertigation is difficult. Moreover, automation is also difficult when we want to give fertilizer along with irrigation water.

There is a pressurized fertilizer tank here it is named as also bypass system to supply fertilizer along with irrigation water. So here, what we see from the diagram, let us try to understand this is a tank. In this tank, the fertilizer, it could be in the liquid form or solid fertilizer which is soluble, the water is supplied from this end. So there is a flexible pipeline and at this place, there is a valve. So water from this pipeline which is coming from the pump it can be supplied with the help of this flexible pipeline which is connected with the inlet plunger pipe.

So inlet plunger pipeline is perforated. Water that is coming it will be getting into the tank. This tank is airtight. It is completely made such that the air cannot enter into the system and it can be opened or capped, so there is a gasket arrangement with the help of lid it can be tightly closed as well as, as and when it is needed it can be opened.

If there is air inside so there is a bleed valve. This helps to remove the entrapped air in this pressurized tank. Now, when the water is being continuously flowing into the system what will happen, it will mix with the fertilizer available in this particular pressurized tank and then there is an inlet end where there is a strainer filter or a strainer screen which is of some certain mesh. It is kept in this particular place so that the dissolved fertilizer which is in the soluble form it can get into the system, that is your irrigation system. So it is allowed to go as long as we keep on allowing the water to get into the system. So this is your inlet kind of thing. And this is the outlet end of the thing that will be allowing the fertilizer solution to get into the pipeline system.

So this is a pressurized fertilizer tank and then there is an inlet and outlet end. Now another important part is the pressure-reducing valve. So pressure reducing valve is operated in such a way that it will allow the pressure to reduce so that the pressure inside the tank is more than the pressure here in the pipeline, then only the soluble fertilizer this can be in the liquid form it can be supplied with the irrigation in the pipeline.

And then it will go to the strainer filter or some other filter whatever it is there it goes to the pipeline. So here it is given the rate of flow of solution is determined by the pressure difference between the inlet and outlet point and is monitored by a flow meter. So flow meter is another device which is used to monitor how much amount of the fertilizer and how much amount of the water is entering into the system.

The difference in the pressure between the connection and constriction in the pipeline is sufficient to cause the flow of water through the tank under pressure. This is the thing which I explained here which I told you the gradient of 0.1 to 0.2 bar is required to redirect an adequate stream of water through connecting tube of 9 to 12 mm diameter.

There is a sealed air-tight pressure supply tank is required to withstand maximum operating pressure. So this is the part which I was telling. This is an air-tight system and then the tank should withstand the pressure which the water it is entering and the water which is going through the pipeline. So it would be more than the pressure inside the tank. So the tank should withstand that pressure.

And then the precise control valves are necessary to maintain a preset injection rate. So the amount of water which is entering into the pipe into the tank, the amount of fertilizer which is coming out of this thing, so that is the rate of injection it can be maintained. Fertigation is cheap and simple. A wide dilution ratio can be attained with no external source of energy.

You can see here this is the arrangement which is shown in the field. There is one end the water is getting into the system, and then it is coming out, and then there is a filter. After it passes the filter then it goes to the pipeline. So this is the arrangement where this is a pressurized tank which is kept on a concrete platform and then the fertilizer is kept into this system and then the flow of water is maintained such that the fertilizer, it can be injected.

What happened there is a continuous supply of water in the tank. So there is a dilution. So concentration initially it reaches to there will be dilution when we are injecting water into the system. So it reaches the concentration, but slowly it starts dissolving and then concentration with time it decreases. So it is unlike in the case of Venturi injector.

Here in this case, which we are seeing here, this is a vertical model. So here, there is water. The water is filled into the system and then inside this flexible bag, the fertilizer solution is kept and when we are supplying water into the system it is pressing so depending on the pressure the amount of fertilizer will be coming out of the system and that will inject into the pipeline.

So this is one model and this is the common normal model where the water is coming and it is getting into the system and then it goes. That is what I explained to you in the previous case. So there is the proportional model which is generally a vertical tank with the sizes varies from 10 to 300 liters.

That will depend upon the capacity or amount of fertilizer one has to inject into the system. If it is a smaller system one should keep on refilling the solid fertilizers which are soluble in the water. The quantitative models could be of 5, 30, 60, 90 120 liter capacity and then this can be made horizontal or vertical tanks that can be used. The nutrient cannot be precisely regulated to each application.

This is what I told you that we cannot maintain the correct concentration. So there is all the time dilution takes place. Valve throttling generates pressure losses and the system is not straightforward. It cannot be coupled with the automated irrigation system, only thing is that this is a simple system and there is low cost. No external power is needed and is relatively insensitive to the changes in pressure or flow rate. However, the tank must be strong enough to withstand the pressure of the irrigation line.

There are limitations. These limitations are there is a varying concentration of nutrients that causes the bulk of fertilizer to be applied at the beginning of the irrigation cycle. So initially it is getting more concentrated fertilizer and then it diluted to the tank must be refilled with a solution for each irrigation cycle. The system is not suitable to connect with automatic or serial irrigation systems.

There is an injection system means that it involves the pumps and then the pump is used to inject fertilizer solution into the irrigation system. This is relatively more sensitive to concentration. One can maintain the concentration in the system. So the solution is means fertilizer solution is pumped from unpressurized reservoir. So this is the reservoir where the fertilizer solution is filled and then it will depend upon the type of pump we are using. So that is making the difference. So it is dependent on the power source.

This particular pump which we are using to inject the system, it could be by using the combustion engine or it can be electric motor driven or the PTO of the tractor that can be used or hydraulic pressure or water engine.

So this here hydraulic pressure type of system is being used. So what we are seeing here, when the fertilizer is to be injected so there is the piston. There is reciprocating motion it takes place. So when we are seeing this is the position of the piston. Now, this piston, what will happen, when the flow of water it is taking place, this flow of water, it will push the piston, it will go back. So this will cause the closing of the valve and then at a certain position the fertilizer is being sucked.

So when the fertilizer is being sucked it will come then the fertilizer will inject here. The piston will come down and then it will make the fertilizer to move up, this particular piston to move up and then it will close. So continuous kind of a flow it will be once it is coming down. So this will push whatever fertilizer it has injected it will push and then this liquid fertilizer it will be pushed into the system. So there is a system where water, as well as fertilizer, dissolves with the system. Both are introduced and these are maintained in a proper proportion. So this is a fertilizer proportional system where the reciprocating type of system where double-acting pistons are used to make it.

So pumping rate and concentration of the stock solution can be adjusted to attain the desired level of fertilizer application. This could be operated by an electric engine or pulse generating water meter so that the fertilizer injected is exactly proportional to the water flow and constant concentration is maintained. Automatic computerized control system are also available to provide the exact rate of injection into the water flow.

And what we see here, after a certain time, when we are introducing water, initially, the water is getting into the tank and then it is reaching and then there is a constant rate of concentration is maintained. So this is the advantage of using the pumps to inject fertilizer along with irrigation water.

There are advantages. There is flexibility and one can maintain a high discharge rate and then the system does not add to the head loss in the prescribed system, this is irrigation. This is the advantage. It maintains a constant concentration of nutrients throughout the period of fertilizer application.

And this is desired in many cases particularly in the hydroponics system where the concentration of certain nutrients which are needed, which should be at a constant rate. So there actually this kind of a system is desired. The limitation or disadvantages, we can say it involves the cost unlike the Venturi system or the pressurized tank kind of a thing. It is having an operational cost because the cost of electricity and maintenance is required.

Now, let us compare the different methods of fertigation which I discussed. I discussed about the bypass tank or bypass pressurized tank. We discussed about the Venturi injector. Just now, I told about the fertilizer pumps, injecting pumps. And then these are the parameters which we are interested to compare these things.

So taking the parameter, at an ease of operation, bypass system, it is highly easily it can be operated. Venturi system, one should take care that whether there is enough pressure difference is created. Then only the Venturi will be sucking the fertilizer. So this is one thing and then from the operational point of view, it is low, there could be a situation where there it is easily operated.

And then use of solid fertilizer. Yes, one can use the solid fertilizer and then because water is entering all the time so that it gets dissolved in time. But in Venturi as well as fertilizer pump one cannot use it. One can use liquid fertilizer, in all cases. The discharge rate is high in case of bypass arraignment. In the case of fertilizer pumps, it requires a high discharge rate. In Venturi injector, it is relatively low.

Concentration control, we cannot have any concentration control in the Bypass tank. It is initially high and then it starts dilution because we keep on adding water. It is a medium for venturi and it is good for pump. Volume control is good, medium, and it is good for these. Head loss, there is low head loss, and then there is a very high head loss takes place from the system, and there is no head loss as the pump is being used.

Automation, one cannot use the Bypass system for automation. This venturi can be to a certain extent, but here also it is medium. But the pump is highly suitable, In most cases, the injection pumps are used means coupled with an automated irrigation system. Price is low, medium, and high. So price is relatively high in the case of the fertilizer injection pumps.

Now, when we are talking about fertigation system design, one needs to know what should be the fertilizer requirement, how to get the value of fertilizer requirement. So fertilizer requirement can be estimated by using this expression where we can get the recommended use of fertilizer minus the available fertilizer multiplied by the fertilizer concentration based on what is the concentration it is needed.

So for each and every crop what is the available fertilizer concentration? Accordingly, this correction factor is multiplied and accordingly, the fertilizer requirement can be estimated.

$$F_n = (R - A_n) \times F_{cf}$$

Where

F_n = nutrient requirement (kg ha^{-1})

R = recommended dose of fertilizer for the crop (kg ha^{-1})

A_n = available fertilizer in the soil (kg ha^{-1})

F_{cf} = fertilizer correction factor

When we want to estimate the fertilizer in each setting, how much is the fertilizer. So the amount of fertilizer for each setting or per setting in kilogram, it can be estimated by using this expression which involves the distance between the emission devices multiplied by the distance between the laterals multiplied by the number of emission devices and then a recommended dose of fertilizer in kg per hectare.

$$D_f = \frac{D_s \times D_e \times N_s \times W_f}{10000}$$

Where

D_f = amount of fertilizer per setting (kg)

D_S = distance between emission devices (m)

D_e = distance between laterals (m)

N_s = number of emission devices

W_f = recommended fertilizer dose (kg ha^{-1})

So this is practically we will be divided by 10,000 it will depend upon the unit we are using. So if you are using in kilogram per hectare, then it is coming in that is to be divided by 10,000 because hectare is being used as a unit.

Now, how to prepare the stock solution. So stock solution means we need to know what is the concentration of a particular fertilizer, nitrogenous fertilizer. So let us say that we want to give 20 kg of nitrogen in a particular place. So assuming that 20 kg of nitrogen is to be used for fertigation. So the amount of urea available is 46%. So for 20 kg nitrogen, the amount required will be 43.5 kg of urea will be adding.

And then we will see what is the solubility of urea. So 1100 gram per liter. So we need to use 40 liters of water to apply the 43.5 kg of urea. And about 50 liter capacity container is enough to store 40 liters of water which will be dissolving the 20 kg urea of means 20 kg of nitrogen which can be given. So we will be using the siphon, the clear solution, and injecting it through the fertigation applicator.

Now, another point is the frequency of fertigation. So what is the frequency of fertigation means we want to give whether it is once in a day or once in every two days or once in a week. So the frequency depends upon the type of system design, irrigation scheduling, soil type, nutrient requirement of the crop, and farmer's preference. So injection duration in fertigation, what should the duration.

So normally, the maximum duration of 40 to 60 minutes is recommended with enough time for flushing and fertilizer residues from the lines before setting up the pump. And the maximum injection duration depends on which type of soil, what is nutrient which we are giving, and what is the water requirement of the crop. So injection duration is sufficient for uniform distribution of nutrients throughout the fertigation zone.

Fertilizer concentration can be computed by using this expression. So this is given by

$$C_f = \frac{100\ F_r}{T_r \times I_d}$$

Where

C_f = concentration of nutrients in irrigation water (ppm)

T_r = ratio between fertilization time and irrigation time

I_d = gross irrigation depth (mm)

F_r = rate of fertilizing irrigation cycle (kg ha^{-1})

So if we are using the fertilizer concentration in ppm and then if we are giving the rate of fertilizer, irrigation cycle in kilogram per hectare and then the ratio of fertilization time to irrigation time is maintained that is given by a time ratio and then the grass irrigation depth is in millimeter. So once we will calculate these numerical problems you will get experience how to find out the fertilizer concentration.

And then one can also find out the fertilizer injection rate. So fertilizer injection rate q_{fi} can be computed by using the expression

$$q_{fi} = \frac{F_r \times A}{c \times t_r \times I_t}$$

Where,

q_{fi} = injection rate of liquid fertilizer solution into the system (Lh^{-1})

F_r = rate of fertilizing (quantity of nutrient to be applied) per irrigation cycle (kg ha^{-1})

A = area irrigated (ha) in time (I_t)

c = concentration of nutrient in liquid fertilizer (kg L^{-1})

t_r = ratio between fertilization time and irrigation time

I_t = duration of irrigation (h)

So using this expression and these units one can find out the rate of injecting liquid fertilizer into the drip irrigation system in liter per hour. And then one can find out what is the fertilizer tank capacity. So fertilizer tank capacity if I want to calculate in liters

$$C_t = \frac{F_r \times A}{c}$$

Where Fr is the rate of fertilizer per irrigation cycle that is in kg per hectare, A is the area irrigated in time t, c is the concentration of nutrient in kilogram per liter. So if you use these units one can get the capacity of the fertilizer tank in liter. So having got these data one can find out the parameter which are required to design the fertigation unit's fertigation components.

So refer to these books which are given here. These books can be used as a textbook and then also you can refer to some of the notes which are available on the internet. So in this particular lecture, we discussed about the theoretical aspect of the fertilizer application method. We discussed about the design of the fertigation system where the different expressions have been used. And then in the forthcoming lecture, we will discuss about irrigation filters. So this is the concluding part of this lecture. And thank you very much.